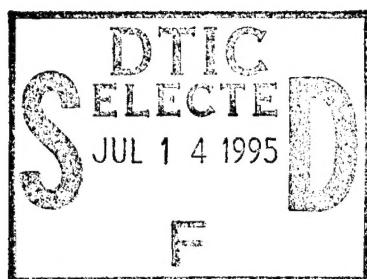


Strategic Leadership in a Changing World Order: Requisite Cognitive Skills

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13. ABSTRACT (Maximum 200 words) This document reviews the psychological literature for models and taxonomies of human cognition. It examines in some detail 20 such models and taxonomies by 18 theorists over a period of 67 years, from 1923 through 1989. The authors conclude that, while there are a number of interesting models, the scientific community does not have a widely accepted, comprehensive theory of cognition or a theory of learning that allows generalization of learning principles to specified complex tasks. Nor does it appear to have a consensus on the concept of intelligence. Above and beyond those considerations, there is little appearance of common purpose guiding the development of the more recently derived models of cognition. The field is more paradigm-driven than theory-driven. No taxonomy of requisite cognitive skills for executive leadership performance was found. The authors, drawing on an integration of the models and taxonomies reviewed, propose such a taxonomy.						
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STRATEGIC LEADERSHIP IN A CHANGING WORLD ORDER: REQUISITE COGNITIVE SKILLS

EXECUTIVE SUMMARY

Requirement:

The research described in this report is a part of a larger program focused on improving the leader development process. An extensive series of interviews of general officers between 1985 and 1989, together with the earlier literature, suggested the importance of cognitive skills, as opposed to knowledge or interpersonal skills, for effective performance at the more senior levels. Two questions immediately became critical. The first had to do with the need for systematic confirmation of these findings. The second had to do with the need for a comprehensive, theory-based architecture within which to fit these skills, i.e., to construct a theoretically sound system within which the skills would fit and that would provide strong indications for how they best can and should be developed.

Procedure:

A preliminary taxonomy was developed, in large part from Stratified Systems Theory and from the initial analysis of the interviews. Four higher order skills were postulated: mapping ability, problem management/solution, long-term abstract planning, and creative thinking. An extensive literature survey was done to identify major theoretical models, on the one hand, and analytic investigations of components of higher order cognitive skills, on the other hand. A total of 20 theories, models, or taxonomies of human cognition were found, covering a span of 67 years. This report describes the major models and systems discovered, provides some integration of them, and relates the integration to the preliminary taxonomy.

Findings:

- The review did not reveal unified thinking in the field on the nature of human mental abilities. There are at least five distinct theoretical groups: (1) comprehensive composite models (e.g., Spearman, Vernon, Burt, Cattell, and Guilford); (2) network models (e.g., Guilford's cube); (3) simply determined hierarchical taxonomies developed by learning theorists and educators (e.g.,

Bloom, Gagne); (4) "cognitive structural" variants (e.g., Van Hiele, Biggs and Collis, and Bucy); and (5) typologies of cognition (e.g., Sternberg, Mumford et al., and Fleishman). The field of inquiry is more paradigm-driven than theory-driven.

- Some coherence seems to be emerging in the most recent literature, as represented by two groups: (1) the (learning) cycles in the cognition stages models of Biggs and Collis, Bucy, Jaques, Van Hiele, and Gagne; and (2) the comprehensive but shallow models of Sternberg, Nickerson, and Martinelli, which are grounded in the work of psychometric and abilities theorists.
- Consensus appears on some points:
 - (1) The literature maintains its long-standing recognition of the separation of cognitive abilities from motor abilities and personality factors.
 - (2) Despite the focus on cognition, there is substantial recognition of the linkage between cognitive skills and the area of beliefs, attitudes, and values.
 - (3) There is general agreement on the differentiation between alpha-numeric reasoning and perceptual-mechanical abilities.
 - (4) The distinction among social intelligence, analytic intelligence, and creative intellect is generally held, arguing for a distinction between critical and creative thinking.
- At the same time, there are sharp disagreements about the nature of intelligence, the place of creativity, the relative order of analysis and synthesis, and the role of evaluation.
- The preliminary taxonomy's generic cognitive tasks of creative thinking, problem solving, and mapping ability are found repeatedly in the models reviewed. Significantly, long-range planning was not found, *per se*. However, *as a task*, it clearly is a requirement as indicated by the interviews, and thus will be retained.
- A progression of difficulty (or complexity) suggests the sequence: mapping ability, problem management/solution, long-term planning, and creative thinking, with a greater separation between creative thinking and the others. The resulting model makes provision for metacognitive skill as a factor in cognitive skill development, though the literature is in great disarray as to the definition of metacognition.

Utilization of Findings:

These findings have been provided to the Department of Command, Leadership, and Management, U.S. Army War College, and will be used in the current program of research in the design of simulation technologies for leader cognitive skill development.

STRATEGIC LEADERSHIP IN A CHANGING WORLD ORDER: REQUISITE COGNITIVE SKILLS

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STRATEGIC LEADERSHIP IN A CHANGING WORLD ORDER: REQUISITE COGNITIVE SKILLS

Clearly, we are very far from a complete theory of the structure and nature of human abilities, and though it is useful to analyze them in isolation as though they were purely cognitive we should not forget that they are abstractions from the total personality structure.

-- Philip Vernon, 1950

THE FRAME OF REFERENCE

Purpose

Research on strategic leadership was directed by the Deputy Chief of Staff for Personnel, Department of Army, in recognition of the singular importance of maintaining the flow of highly qualified officers through the Army's leader development system into the pool of senior colonels from which general officer selections are made. Early findings from the research program suggested the importance of cognitive and metacognitive skills. This consequently became a strong focus of the overall effort.

Two key questions were evident. First, do cognitive skills grow over time, at least for some people, into late adulthood? Second, is there a progression of cognitive skill complexity, such that one serves essentially as a building block for another? The present effort attempts to answer these questions. Specifically, it is an effort to construct a preliminary taxonomy of cognitive and metacognitive skills for strategic leadership. At least two methods of inquiry operated in tandem: a review of several relevant scientific literatures and content analyses of interview transcripts from 40 incumbent U.S. Army Generals.

The literature review examines the theories, models, and taxonomies of cognitive skills in the empirical literature of the cognitive sciences. Theories of mental abilities began to emerge in the early decades of this century; they and their descendants form the basis of intelligence tests as we know them. Notable are the theories of Spearman (1923), Burt (1949), Vernon (1950), Guilford (1967), and Cattell (1971).

Work in mental abilities over this century clusters into two time periods: the first encompasses the first 50 years of the century, and the second begins during the decade of the 1980s, after a period of more particularized inquiry. The most recent work on models of cognitive skills is characterized by dissension and attempts to reintegrate intelligence as traditionally measured (e.g., Jensen, 1987) with a broader concept of intellect to include the

constructs of wisdom¹ and creativity (e.g., Nickerson, 1990; Sternberg, 1989), among others. All told, there appear to be 11 more or less complete taxonomies of cognitive skills in the empirical literature. These taxonomies were developed by Bloom et al. (1956), Guilford (1967), Gagne (1970), Cattell (1971), Fleishman (1975), Biggs and Collis (1982), Mumford et al. (1986), Vandendorpe (1985), Van Hiele (1986), and Bucy (1989) borrowing from Jaques (1985). How good they are, and how relevant to this purpose, will be discussed in this review.

This study addresses cognitive skills thus far under-recognized in the empirical literature on strategic leadership in order to create a more general theory and to support intervention strategies for adult development. It is not expected at this stage of the research that any one taxonomy will directly support the preliminary taxonomy developed here, although several taken together may do so. Rather, existing taxonomies will be evaluated for the degree to which they support or disconfirm the preliminary taxonomy. Where possible, preliminary results from the content analysis of the General Officer interview transcripts will be used to exemplify and explicate the cognitive processes under discussion.

The Preliminary Taxonomy

A taxonomy is a structural model organized by a set of consistent principles that dictates the elements within it. It is not a serial listing of items or units, whether, as in the case of a taxonomy of cognition, they be cognitive processes or traits (e.g., Fleishman, 1975). **A taxonomy must be testable and predictive of phenomena yet to be discovered. It may be tested by determining whether or not it is consistent with the empirical evidence and/or sound theoretical positions in the field** (Krathwohl et al., 1964). And, "while it is not necessary to have empirical support at every point, there should be enough empirical foundation to support the superstructure that is built upon it" (Guilford, 1967, p. 48).

The taxonomy of cognition² to be proposed is a four-part model consisting of **metacognition**,³ **generic cognitive tasks**,⁴ **higher-order cognitive processes**,⁵ and **component cognitive skills**⁶ (Figure 1). Note that the cognitive tasks, processes, and skills are surrounded and embraced by metacognition and its broader aspect, reflective self awareness. The taxonomy is also referenced to two particular criteria of intellectual performance--strategic leadership and superior capability--on the assumption that the two should intersect to some as yet undetermined degree.

In this analysis, the focus is exclusively on higher-order cognitive tasks and skills; interpersonal skills, also crucial to effective functioning at the strategic leadership level, have been set aside. At this stage of the work, metacognition as further specified will not be elaborated until the analysis and configuration of generic cognitive tasks and higher-order cognitive skills is taken further than the level of analysis expressed here. Metacognition here is meant merely to suggest the direction to be taken in its interpretation. The comprehension strategies of adroit readers, for example, in interpreting text--the reconstruction of scenes,

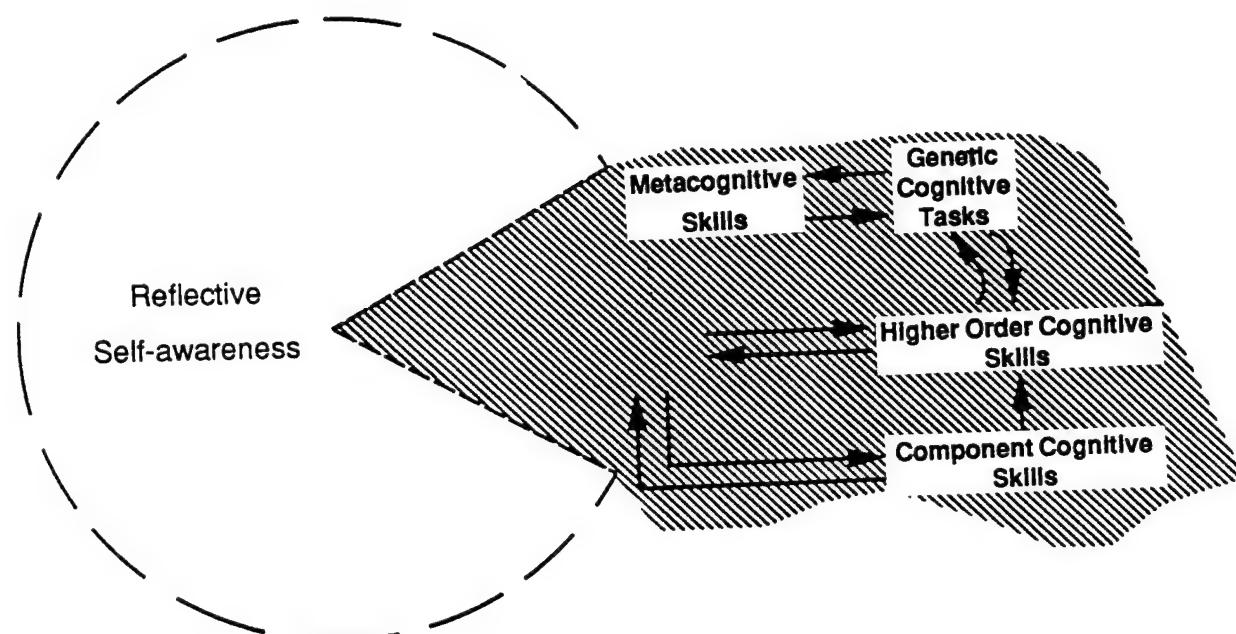


Figure 1

Cognitive Capabilities for Executive Development:
A Four-Part Conceptual Model

the conscious questioning of fact and implication--will probably not be addressed directly. The reasons for this deliberate moratorium are that the generic cognitive tasks and higher-order cognitive skills most essential to and perhaps even defining effective leadership must first be determined before they can be sensibly configured and the metacognitive strategies with which they interact can be identified and explicated. As reading comprehension is very likely not an information-processing capability most definitive of effective leadership, the metacognitive strategies that interplay with it would likewise not be evaluated. Once determined--first the "defining" generic cognitive tasks and higher-order cognitive skills and then the metacognitive⁷--the examination of the interactions are expected to be highly complex and not necessarily obvious from the literature. It is expected that the more complex the cognitive process, the more conscious an individual becomes of it, or at least of aspects of it.

Four higher-order cognitive tasks were determined, each with its particular champions. The tasks are mapping ability, problem management/solution, long-term abstract planning, and creative thinking. According to Jacobs and Jaques (1990a), mapping ability is an essential cognitive skill. By weight of their argument, it is the cornerstone for informed, rational, and principled problem management and planning. "If decision making is viewed more from the perspective of information processing behavior, focusing on search, acquisition, evaluation and feedback learning, avenues may well be found to improve decision performance through attention to environmental and individual factors that influence those processes." (Jacobs, 1983, p. 3). By direct assertion, however, problem management and solution is the essential cognitive skill for effective strategic leadership. "It may well be the highest priority task at the executive level." (Jacobs and Jaques, 1987, p. 23). General William R. Richardson, former Commander of the Training and Doctrine Command, U.S. Army, in arguing for more formal education of officers in higher-order cognitive skills, stressed the ability to plan in the abstract over the long term as the critical ability (Richardson, 1984). And Cronin (1984), of the Center for the Study of the Presidency, favors creativity. "Leadership at its best comes close to creativity." (Cronin, 1984, p. 25)

Each of these four higher-order cognitive tasks was divided into hierarchically organized components, using a theoretical deductive approach. The notion of a hierarchical taxonomy of generic cognitive tasks and higher-order cognitive skills resting on component cognitive elements has precedent (Spearman, 1923; Vernon, 1950; and Jensen, 1970). In fact, hierarchical models are common, particularly in psychometric theories of intelligence (e.g., Jensen, 1970; and Vernon, on the basis of test scores, 1950). There are, at the same time, certain distinctive features of this taxonomy. Component higher-order cognitive processes, for example, appear to cross-cut several generic cognitive tasks that are thereby connected. The taxonomy proposed will be discussed in more detail in later sections of this report.

Method

This taxonomy was developed from a real world, componential cognitive task analysis in which the elements (major generic cognitive tasks) are thought of as successive layers of underlying components. Leadership theory, particularly concerning cognitive skills thought critical to leadership, was reviewed to determine which higher-order cognitive skills were favored by either the weight of empirical evidence or an especially well-argued position. Such a position is that of Elliot Jaques and T. O. Jacobs (1990a, 1990b, 1987). It was interesting to refer, where possible, to the theories of bureaucracy and personal development they espoused. The notion of a cognitive taxonomy is certainly suggested by their writings⁸ (Bucy, 1989). "The theory suggests that there is a progression of thinking skill requirements from concrete to abstract analytical to abstract integrative. Is there really such a progression? If so, is individual development progressive, or were executives always capable of abstract integration?" (Jacobs and Jaques, 1990b, p. 284).

In addition to theoretical deduction, observations by experts in the field of strategic leadership, especially military leadership, on cognitive tasks and skills critical to and performed for real world positions or ranks were analyzed.

Although there was no singular weight of evidence, four higher-order generic cognitive tasks emerged. These were further divided into general, class, and specific components, higher-order cognitive skills, on the basis of a literature review in the fields of psychology, logic, and artificial intelligence; they were then authenticated against the introspective self-reports of 40 incumbent three- and four-star U.S. Army Generals. Thus, certain abilities were tied to particular task requirements where tasks are viewed as mental processes or schemas. Component cognitive skills (for example, pattern recognition, spatial relations, and auditory recall) were not evaluated as independent entities.

A more comprehensive review entailing two levels of search has been done. The present report addresses comprehensive theories, models, or taxonomies; the second will address partonomies, or taxonomies for components of particular generic cognitive tasks or higher-order cognitive skills, with which the psychological literature appears to abound (Rips and Conrad, 1989). Examples of the latter are Brooks (1989), Taylor and Evans (1985), and Wang and Hwang (1989).

The research operated on two parallel tracks. The first literature review was largely independent of construction of the taxonomy, which was primarily a priori. The fundamental expectation was that other existing taxonomies will be different enough or incomplete enough not to materially abet the configuring of the taxonomy in progress. Thus, the major purpose of the research was to find persuasive disconfirming evidence, if such existed. The second literature review operated in tandem with the in-depth data analysis performed on the U.S. Army General Officer interview transcripts, and is reported separately.

THEORIES, MODELS, AND TAXONOMIES OF COGNITIVE SKILLS

As noted earlier, theories of cognitive abilities began to emerge in the first decades of this century. The work clusters into two time periods. The first encompasses the first 50 years of the century and the second begins during the decade of the 1980s. Notable are the theories of Spearman (1923), Burt (1949), and, later, Vernon (1950), Cattell (1971), and Guilford (1967). A then-new psychometric methodology--factor analysis--fueled the early burst of activity, as well as the hope that the measurement itself might be a means for identifying and relating the major cognitive abilities.

At least three schools--the psychometric theorists (e.g., Vernon and Jensen), the learning theorists (e.g., Bloom and Gagne), and the ability theorists (e.g., Guilford and Fleishman)--are evident. Among the learning theorists, Gagne has been characterized as the most systematic in the specification of "learning categories" and their potential for structuring principles of learning. The ability theorists have tried to isolate and integrate dimensions of behavior within the framework of experimental psychology on which a general theory of human performance might be founded. This line of inquiry includes Thurstone's work on primary mental abilities and reached its most elaborate expression in Guilford's extensive program of research. The most recent work on models of cognitive skills is characterized by dissension and attempts to reintegrate intelligence as traditionally measured (e.g., Jensen, 1987) with a broader concept of intellect to include, for example, the constructs of wisdom and creativity (e.g., Nickerson, 1990; Sternberg, 1989), among others. All told, there appear to be 11 more or less complete taxonomies of cognitive skills and at least 3 major theoretical precursors in the empirical literature of the cognitive sciences. Three incomplete models are also reviewed because of current interest in them. The 11 complete taxonomies are by Bloom et al. (1956), Guilford (1967), Gagne (1970), Cattell (1971), Fleishman (1975), Mumford et al. (1986), Biggs and Collis (1982), Vandendorpe (1985), Van Hiele (1986), and Bucy (1989) borrowing from Jaques (1985).

The definition of taxonomy presented earlier will be adhered to in the course of the following appraisal of theories, models, and taxonomies of cognitive skills. To repeat: a taxonomy is a structural model organized by a set of consistent principles that dictates the elements within it. It is not a serially listed classification scheme, whether, as in the case of a taxonomy of cognition, the units or items be cognitive processes or cognitive traits. A taxonomy must be testable and predictive of phenomena yet to be discovered. It may be tested by determining whether or not it is consistent with the empirical evidence and/or sound theoretical positions in the field. Its principal purpose is to interpret or predict some facet of human performance. A taxonomy of cognition should also pay some attention, given the state of the art, to metacognition, higher-order cognitive processes, and other component cognitive skills.

In all, 18 theorists and 20 theories, models, or taxonomies of human cognition were reviewed after a comprehensive literature search. They cover a span of 67 years and a variety

of notions about the structure of human cognition. It was decided at the outset that all taxonomies of cognition worthy of the label would be sought, not only those having to do with expert performance or, more narrowly, strategic leadership. How good the taxonomies are, indeed how relevant to this purpose, is, of course, a different issue, one that will be discussed in this report. The fact remains that, despite previous research, there is as yet no comprehensive system, no general theory, that effectively compares, contrasts, and integrates the various human cognitive abilities or "learning categories" into a plausible model of human cognition. Table 1 identifies the theorists and models to be discussed and includes characteristics and year of conception.

THEORETICAL PRECURSORS

The notion of a hierarchical taxonomy of cognitive skills resting on component cognitive elements is rooted in early 20th century British psychology. Three British theoreticians in the first half of the century laid the foundation for later advocates of hierarchically ordered cognitive abilities as the proper view of human thought: Charles Spearman, Cyril Burt, and Philip Vernon. Their designs were grand, agreeing in principle although differing in emphasis. Spearman (1923) emphasized underlying process, Burt (1939 and 1944) perceived mental abilities as both abilities and factors in a broader scheme, and Vernon (1950) confined himself largely to the structure of human abilities.

In Great Britain, the importance of a general factor, *g*, or general intelligence, was demonstrated by Spearman as early as 1923. The existence of additional subordinated abilities gradually emerged, primarily from the work of Sir Cyril Burt, from 1905 through 1944. Results obtained from analyses of British Army recruits during World War II confirmed the hierarchical theory that certain principal types of ability exist and that these can be subdivided into minor abilities. In American psychology, however, the predominant view was that all mental abilities were highly specific. Guilford in the United States, for example, in 1938 opposed the idea of a hierarchy, arguing instead for a number of independent types of ability, which Spearman once labeled "the anarchic theory of mental structure."

Spearman's Hierarchies of Intelligence and Elementary Processes

The notion of a hierarchical taxonomy of cognitive skills resting on component cognitive elements may have originated with Spearman. His theory, which is marvelously rich, is made up of two distinct, hierarchically organized aspects. One is Spearman's two factor theory of intelligence, labeled a "general energy and specific engines" theory by Burt (1939). The other is his elementary processes hierarchy, on which he superimposes four cognitive faculties--sense or perception, memory, intellect, and imagination (or invention or

TABLE 1
Theorists and Models of Cognition Reviewed

Theorist	Model Name	Characteristics	Year of conception
1. Charles Spearman	1. Hierarchies of Intelligence and Elementary Processes	Attempts comprehensiveness. Two hierarchical structures: one factor analytic; the other psychological.	1923
2. Cyril Burt	2. Structure of the Mind	Attempts comprehensiveness. Idealized hierarchy in which theory and analysis are out of alignment.	1949
3. Philip Vernon	3. Hierarchical Structure of Human Abilities	Attempts comprehensiveness. Hierarchical; derivative of empirical work using factor analysis.	1950
4. Benjamin Bloom	4. Taxonomy of Educational	Attempts comprehensiveness. Hierarchical. Asserts cognitive behaviors in terms of educational outcomes. Learning-theory based.	1956
5. Robert Gagne	5. Hierarchy of Learning Types	Narrowly defined. Hierarchical. Tightly organized. Highly influenced by learning theory.	1970 1985
	6. Learning Outcomes	Typology of five outcomes of types of learning, each outcome having all learning types embedded.	1984 1985
6. Raymond Cattell	7. Triadic Theory of Cognitive Abilities	Attempts comprehensiveness. Hierarchical. Attempts interactive model of underlying process. Derivative of factor analysis.	1971
7. J. P. Guilford	8. Structure of the Intellect Cube	Comprehensive. A network model. Factor analytic methods used, highly controversial.	1967
8. Edwin Fleishman	9. Fleishman's Taxonomy of Cognitive Abilities	A list of cognitive abilities derived from experimental work, neither hierarchically nor cross-sectionally organized.	1975
9. Michael Mumford	10. Mumford's General KSAO Taxonomy: Cognitive Abilities	A list of cognitive abilities attempting to describe requisites for effective military officer performance.	1986
10. Flynn Bucy	11. Quintave Typology of Reasoning	Four levels of problem solving hierarchically organized by level of abstraction.	1989

TABLE 1 (Con't)
Theorists and Models of Cognition Reviewed

Theorist	Model Name	Characteristics	Year of conception
11. Elliott Jaques	12. Model of Cognitive Functioning	Complex hierarchical model. Cognitive modes are embedded into cognitive strata organized by abstraction and information richness.	1985
12. Biggs and Collis	13. SOLO Taxonomy	Five-level, cumulative hierarchy explicitly equated to Piagetian developmental stages.	1982
	14. Extended SOLO Model	Learning cycles from simple to complex nested within each of the five levels.	
13. Peter Van Hiele	15. Levels of Thought and Learning	Five-level, hierarchical model and developmental sequence, each level having five embedded, repeating phases of learning.	1986
14. Mary Vandendorpe	16. K-D Tree for Human Cognition	Binary and hierarchical. Attempts to explain learning, forgetting, divergent and convergent thinking.	1985
15. Raymond Nickerson	17. Implied Taxonomy of Higher-Order Thought	Posits and verbally configures higher- and lower-order cognitive skills.	1990 1989
16. Kenneth Martinelli	18. An Unjustified Taxonomy	Posits and verbally configures higher- and lower-order cognitive skills.	1987
17. Robert Sternberg	19. Three Sets of Intelligence	A typology and, more, an implied ordinal scale of differing intellects.	1989
	20. Outline of Mental Abilities	Identifies four components in cognitive tasks.	1979

origination), which "has been more or less clearly conceived as the creative power of the mind." (Spearman, 1923, p. 326).

Spearman explains intelligence as follows (1923, p. 5):

The continued tendency to success of the same person throughout all variations of both form and subject matter--that is to say, throughout all conscious aspects of cognition whatever--appears only explicable by some factor lying deeper than the phenomenon of consciousness. And thus, there emerges the concept of a hypothetical general and purely quantitative factor underlying all cognitive performances of any kind. Such a factor as this can scarcely be given the title of "intelligence" at all; being evoked to explain the correlations that exist between even the most diverse sorts of cognitive performance.... On this view, the name is commonly written in inverted commas, or else replaced by the simple letter g.... The factor was taken, pending further information, to consist in something of the nature of an "energy" or "power," which serves in common the whole cortex (or possibly even the whole nervous system).

But if, thus, the totality of cognitive operations is served by some general factor in common, then each different operation must necessarily be further served by some specific factor peculiar to it. For this factor also a physiological substrate has been suggested, namely, the particular group of neurons specially serving the particular kind of operation. These neural groups would thus function as alternative "engines" into which the common supply of energy could be alternatively distributed.

The two hierarchies are interconnected by Spearman's equating intelligence with **intellect** and **imagination** (Spearman, 1923, p. 338). His hierarchies are combined here and depicted in Figure 2. Spearman bases his hierarchy in human development. The acquisition of the three components of intellect--reasoning, "the highest level of the intellect"; judgment; and conception, or concept formation--are cast as a developmental sequence by statements such as: "... the second great stage in the development of the intellect is judgement." Similarly, the qualities of intensity, determinateness, and speed are said to improve with preadult development.

Spearman goes so far as to specify interactions among subprocesses, taking special care with "creative power."

The creative faculty of the mind shows itself to be always at bottom some eduction of correlates [abstractions related into higher-order abstractions] to which there may or may not be added an immediately following and intimately cooperating reproduction [reproduction being one of the elements of memory]. (1923, p. 338)

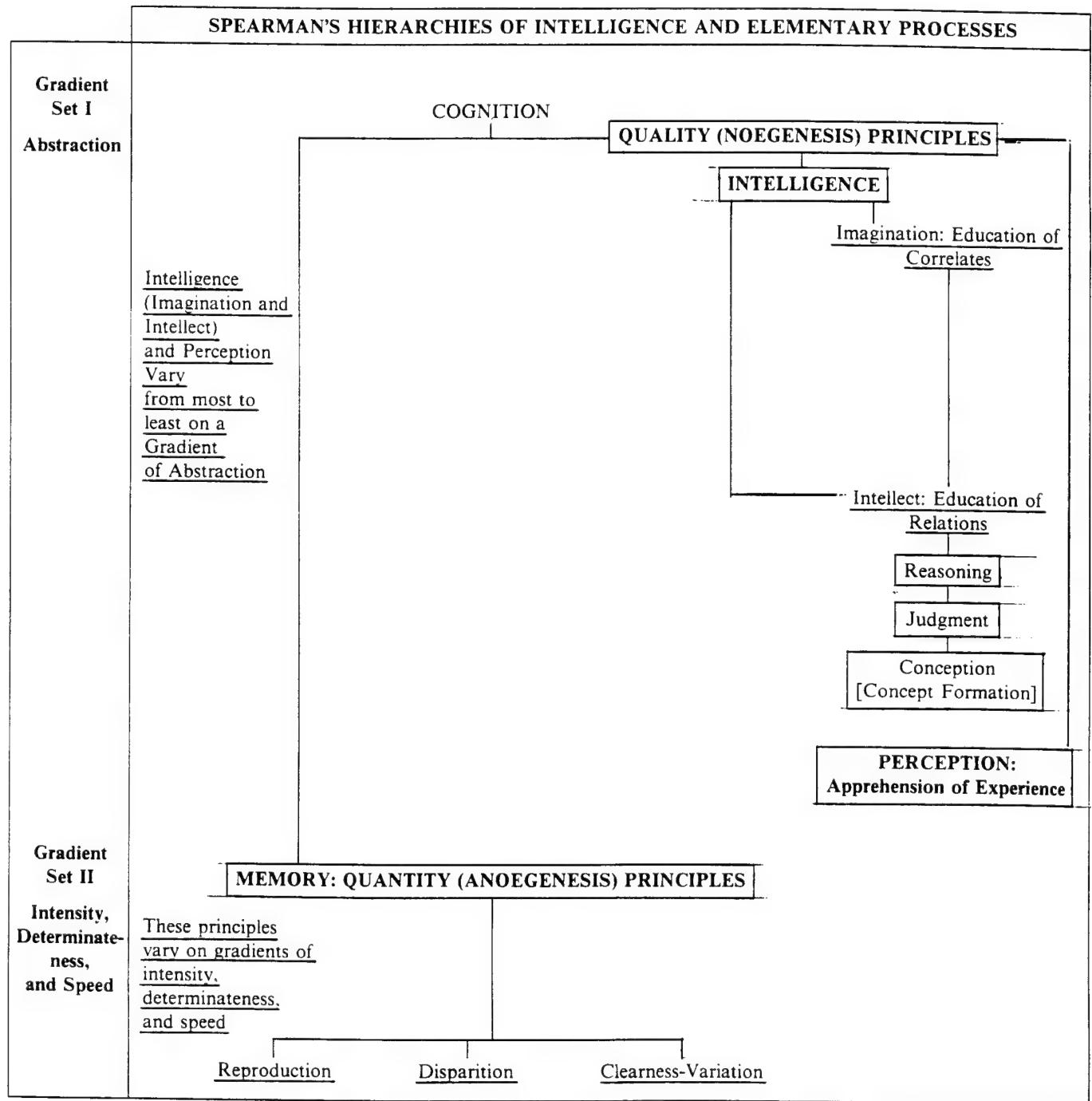


Figure 2.. Spearman's Hierarchies of Intelligence and Elementary Processes

Spearman does not interweave his two hierarchies further than this by, for example, specifying which subpowers relate to specific subprocesses. However, it would be fair to assume that the subpowers, which he never identifies, are either isomorphic with or related closely to the subprocesses, which he does determine. This failure to identify the subpowers measured by the intelligence tests of his day with the subprocesses he more carefully lays out foreshadows the dilemma reflected in more modern taxonomies of human cognition--where to place and how to analyze intelligence.

Vernon's Hierarchical Structure of Human Abilities

Vernon, in marked contrast to Spearman, sticks closer to hierarchies derived from factor analysis. He postulates a four-level hierarchy of constituent cognitive skills, as opposed to Spearman's two-factor theory and Burt's three-factor (general, group, and specific) constituent hierarchical analysis. Vernon's hierarchical structure of human abilities is given in Figure 3.

This model encompasses the whole of the human mind. The first major subdivision is between intellectual abilities, or the **g** factor, and **X**, defined as "factors of personality and interests" but represented in some parts of the exegesis as factors of physique. **X**, in truth, is an "other" category; everything but cognition goes in this bucket. Most striking is the persistent separation between the two major group factors: v:ed, alpha-numeric reasoning, as opposed to k:m, characterized as spatial-perceptual and mechanical-manual. Vernon (1950, p. 9) observes, "Clearly, visual imagery has something to do with k," and again, (Vernon, 1950, p. 47) "the k:m factor probably links up with scientific ability...." The lynchpin between alpha-numeric reasoning and visualization is scientific ability, as depicted in Vernon's structure of educational abilities (1950, p. 47). These two recurrently separate factors appear analogous to the specialization in cognitive processing and abilities currently posited for the right and left hemispheres of the human brain.

Burt's Idealized Hierarchy

Burt's model, unlike Vernon's, is an idealized hierarchy with successive bifurcations. Each division of a factor yielded two immediately lower. Yet his empirically derived factors did not quite fit his model of the mind and of mental aptitudes. For some levels of generality, he had derived many more factors than aptitudes. For example, at the association (per model)-general factor (from statistical analysis) level, he identified memory (with a general retentiveness factor); productive association (with a general inventiveness factor), and verbal, language, and arithmetical abilities.

At the level of perception under memory were derived visual, auditory, aesthetic and verbal memory factors but clearly (see Figure 4) only two fit. Burt attempted the distinction between abilities and factors but never clarified it (Burt, 1944).

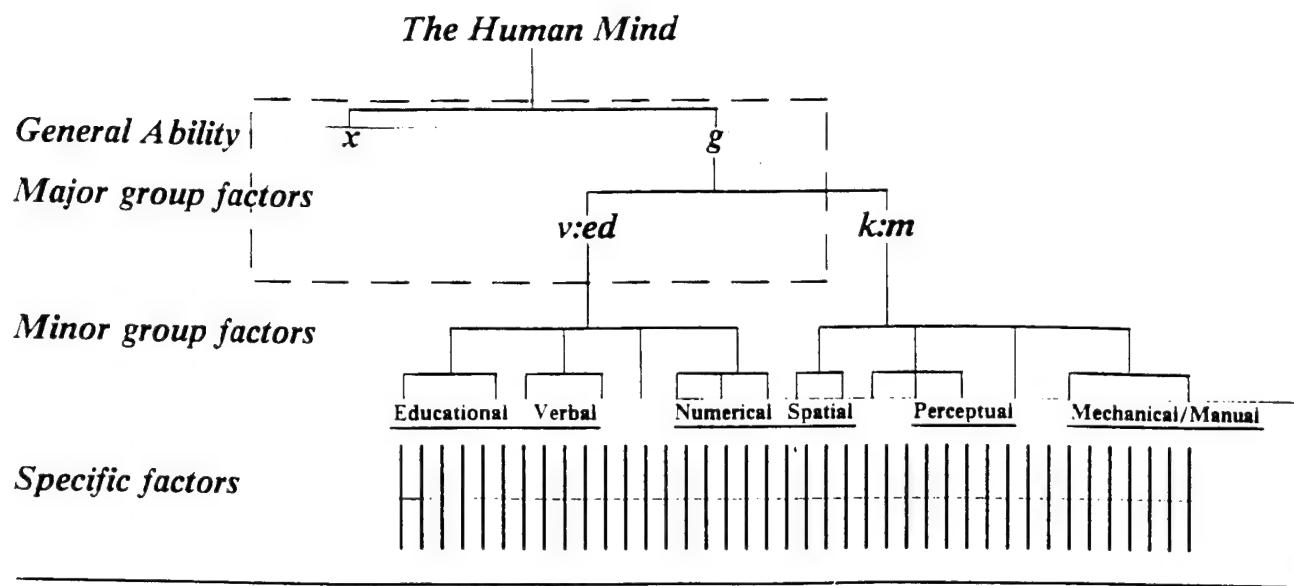


FIGURE 3. Vernon's Hierarchical Structure of Human Abilities

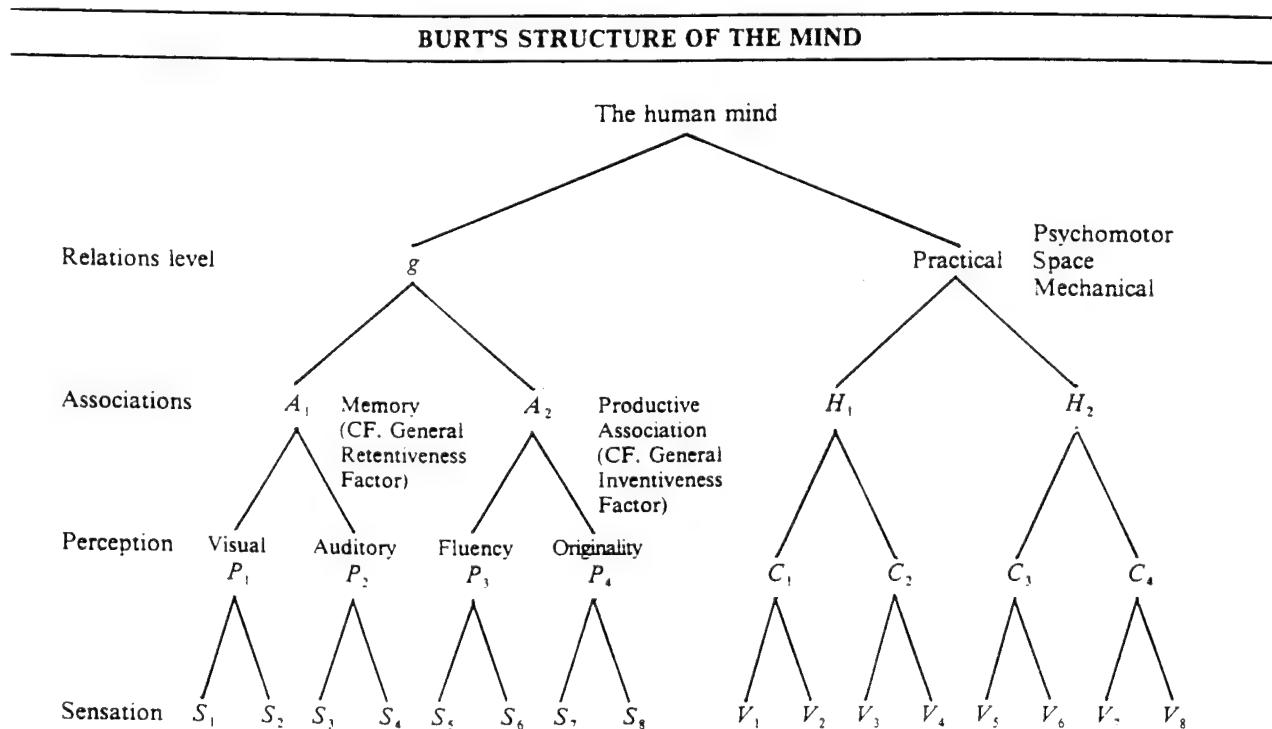


FIGURE 4. Burt's Structure of the Mind

Note: From The structure of the mind: a review of the results of factor analysis. By C. Burt, 1949. British Journal of Educational Psychology, 19. Copyright 1949 by British Psychological Society.

THE TAXONOMIES

The Classics

The classic taxonomies in the field of cognitive psychology are Bloom's taxonomy of educational outcomes (1956) and Gagne's hierarchy of learning types (1970). Both taxonomies lie squarely in the area of learning theory. Bloom's taxonomy has been widely accepted by educationalists and is used extensively in setting educational objectives and in test construction.

Bloom's Taxonomy of Educational Objectives. Bloom's taxonomy, despite a somewhat misleading title, is in fact a classification of cognitive behaviors that represent the intended outcomes of the educational process (Bloom et al., 1956, p. 12). Elsewhere, the cognitive domain is said to **include** learning objectives that deal with the development of knowledge and intellectual abilities and skills identified as "reasoning, problem solving, concept formation and, to a limited extent, creative thinking" (p. 15). A great deal of Bloom's taxonomy devotes itself to specifying the external behaviors of students in educational settings that could be taken as evidence that an individual is capable of the process targeted, at least with respect to a particular piece of information or problem. The flip-flop and two-fold objective notwithstanding, the emphasis is clearly on cognitive abilities, represented as underlying processes made manifest in product, either knowledge or behaviors.

More disconcerting is the fact that the taxonomy deals very little with the aforesaid intellectual abilities and skills--reasoning, problem solving, concept formation, and creative thinking. Bloom's taxonomy (Bloom et al., 1956) contains six major classes arranged in a cumulative hierarchy and 20 subclasses, arranged within classes from least to most abstract, all couched as learning objectives.¹ The classes are knowledge, comprehension, application, analysis, synthesis, and evaluation. Underlying the taxonomy is the assumption that the classes represent an increasing complexity of cognitive function, from simplest knowledge to most complex evaluation.

Doubtless, Bloom believes the taxonomy to be hierarchical: "the more complex behaviors include the simpler behaviors."

We can view the educational process as one of building on the simpler behavior. Thus, a particular behavior which is classified one way at a given time may develop and become integrated with other behaviors to form a more complex behavior which is classified in a different way. In order to find a single place for each type of behavior, the taxonomy must be organized from simple to complex classes of behavior. Furthermore, for consistency in classification, a rule of procedure may be adopted such that a particular behavior is placed in the most complex class which is appropriate and relevant. (Bloom et al., 1956, p. 16).

A criticism laid against Bloom's taxonomy is that the relationship among the classes, though hierarchical, is one-directional (Paul, 1985). For instance, comprehension presupposes knowledge but knowledge does not presuppose comprehension. Knowledge, Paul argues, cannot be separated from comprehension and rational assent.

Bloom himself recognizes that this is true. Knowledge--little more than the recall or recognition of an idea or phenomenon--"may also involve the more complex processes of relating and judging." (Bloom et al., 1956, p. 62). And, similarly, "It is true that analysis shades into evaluation, especially when one thinks of 'critical analysis'." (Bloom et al., 1956, p. 144).

With respect to the issue of whether or not the hierarchy represents an invariant ordering in thought processes, Bloom's observations on evaluation are most significant.

Although evaluation is placed last in the cognitive domain because it is regarded as requiring to some extent all the other categories of behavior, it is not necessarily the last step in thinking or problem solving. It is quite possible that the evaluation process will in some cases be the prelude to the acquisition of new knowledge, a new attempt at comprehension or application, or a new analysis and synthesis." (Bloom et al., 1956, p. 185).

Moreover, for Bloom, the hierarchy of educational outcomes is more than a construct for modeling cognitive behaviors. For example, evaluation represents both an end process in dealing with cognitive behaviors and a "major link" with the affective behaviors where "values, liking, and enjoyment are the central processes." (Bloom et al., 1956, p. 185). Similarly, synthesis is "the category in the cognitive domain which most clearly provides for creative behavior." (Bloom et al., 1956, p. 162).

It would seem that some educators preoccupied with the value of the taxonomy for instruction have taken it in its simplest, most literal sense.

Nevertheless, real concerns remain about how to measure the degree of complexity for each of these processes. Are they all to be judged as equally related so that the distance between, for example, comprehension and knowledge is the same as that between synthesis and evaluation? Bloom indicates a major break between knowledge, the lowest, most basic class of behaviors in the hierarchy, and intellectual abilities and skills, which comprise the rest.

While it is recognized that knowledge is involved in the more complex major categories of the taxonomy, the knowledge category differs from the others in that remembering is the major psychological process involved here, whereas in the other categories, remembering is only one part of much more complex processes [emphasis added]." (Bloom et al., 1956, p. 62).

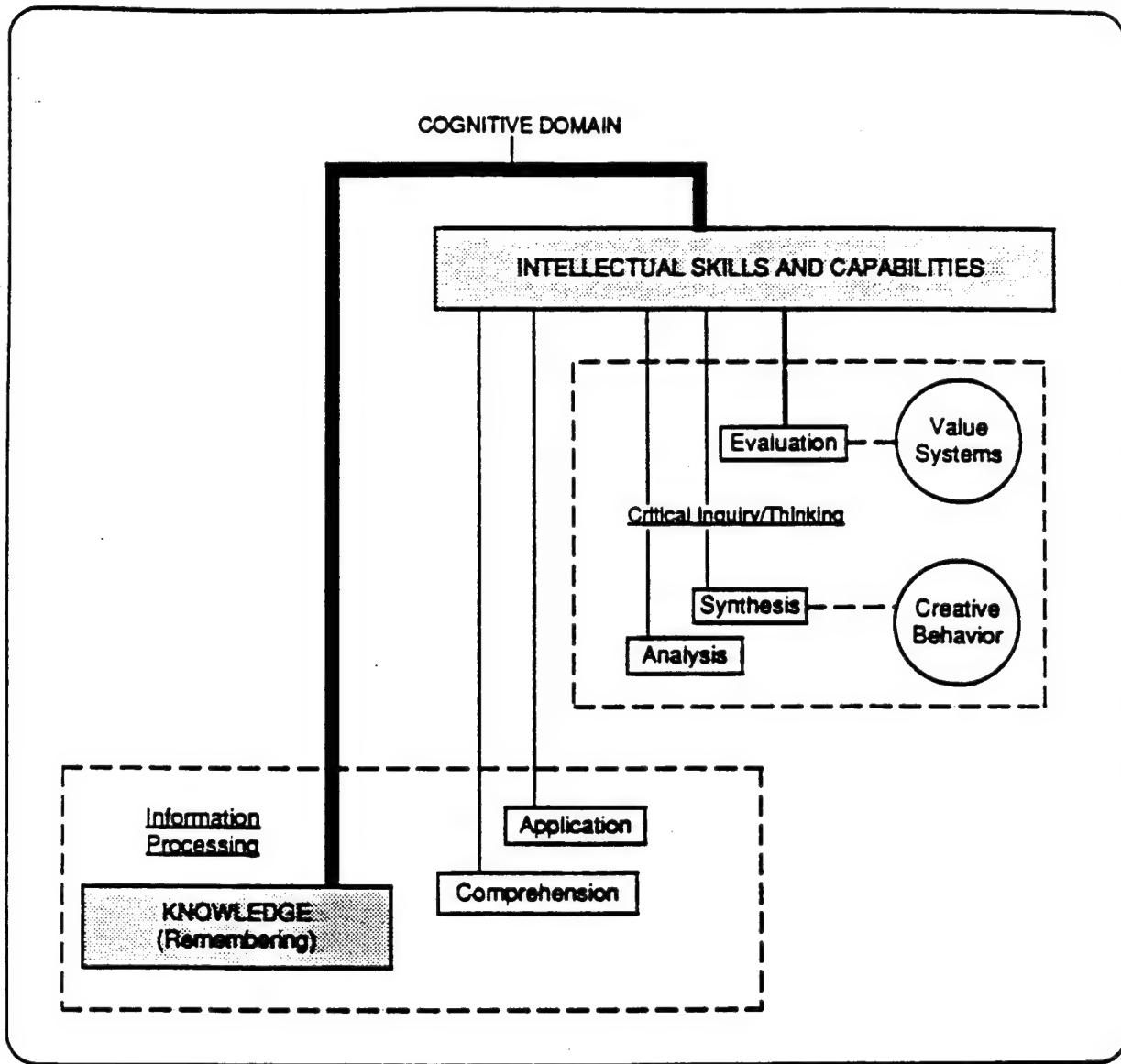
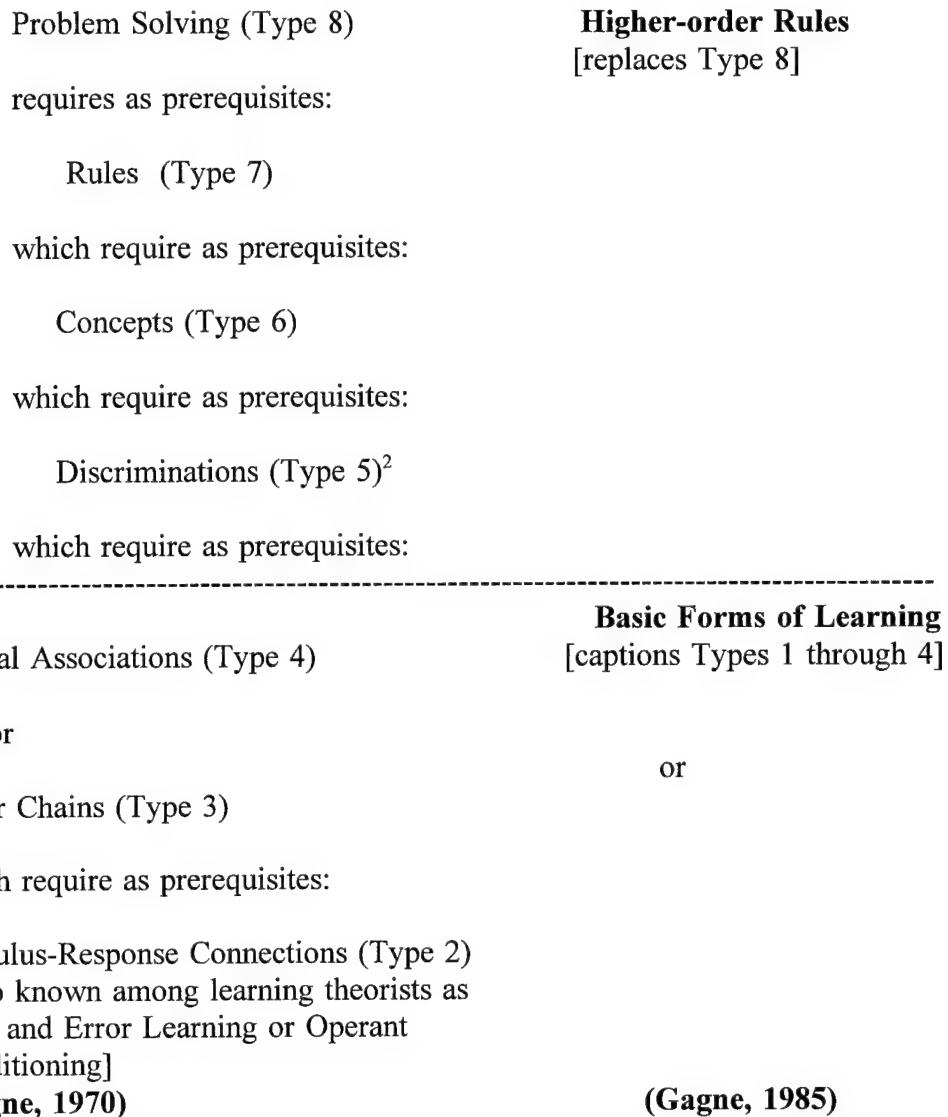


Figure 5. Bloom's Taxonomy of Educational Outcomes Plus

FIGURE 6
Gagne's Hierarchy of Learning Types



For the rest of the classes, there are no comparable observations.

In addition, some cognitive behaviors would seem better placed elsewhere. The highest subclass of comprehension--extrapolation--is defined as making estimates or predictions based on understanding the trends, tendencies, or conditions described in communication. This ability would seem better placed among reasoning abilities, more specifically, the reasoning of approximate implication.

There must also be concern about the consistency of principle entailed in the selection of the six classes. The major inconsistency appears with application, and, second, with comprehension. These classes, particularly application as defined, read very much like tests of an individual's awareness, use, and control of a cognitive process. Bloom asserts that a "demonstration of comprehension shows that an individual can (awareness and use) use an abstraction when its use is specified. A demonstration of application shows he will (control) use it correctly." (Bloom et al., 1956, p. 120). Bloom further distinguishes application by saying it is "use of an abstraction in real life (Bloom et al., 1956, p. 122).... in particular and concrete situations." (Bloom et al., 1956, p. 205).

Solman and Rosen (1986) conducted two experiments to examine Bloom's contention that the complexity of the cognitive operations required by each class in the hierarchy increases with their level in it. Percentages of correctly completed test items said to measure each of the six classes confirmed the order but not the presumptions about relative degrees of complexity. In the one experiment for which such differences were reported, analysis and synthesis were significantly more difficult tasks than comprehension and application, with no significant statistical differences within each pair. Both pairs were significantly more difficult than the knowledge task and significantly easier than evaluation.

Bloom's taxonomy, presented in its condensed version,¹ is relevant to modern attempts to model the structure of mental abilities for instructional purposes. Knowledge, though simplest, is "basic [i.e., the most fundamental and presumably therefore the most important] to all the other ends or purposes of education. Problem solving or thinking cannot be trained in a vacuum but must be based upon knowledge of some reality." (Bloom et al., 1956, p.33). Knowledge of specifics and universals and of ways and means of dealing with them foreshadows the latter day distinction between declarative and procedural knowledge. Certainly the two most basic cognitive processes in the hierarchy, remembering and comprehending, as defined, are aspects of information processing, which undergirds the higher-order processes identified in the preliminary taxonomy being constructed. Moreover, Bloom's views on the relationship between certain cognitive skills and other aspects of the mind are provocative, particularly those with regard to creativity and individual value systems. If these and the basic taxonomy are compiled, the following broader model can be obtained. See Figure 5.

Gagne's Hierarchy of Learning Types (1970) and his Outcomes of Learning (1985)

Over the course of two decades, Gagne has provided at least two classification schemes for human learning. One of these, his "**hierarchy of learning types**," (Gagne, 1970; Gagne, 1985) is a taxonomy by the definition given herein. The other, the five **outcomes of learning**

(Gagne, 1984), addresses what is learned--the "five main categories of learned capabilities; these categories are comprehensive." (Gagne, 1985, p.48) The second classification begs the nature of its scheme (Is it a taxonomy?) and its relationship, if any, to the earlier work.

The hierarchy sets out eight learning categories, seven of which are depicted in Figure 6. The differences between the 1970 and 1985 versions of the hierarchy appear in bold to the right.

In the careful words of a scientist, Gagne (1970) explains away one learning type:

While it may be true that stimulus-response connections (Type 2, Figure 4) require signal learning (Type 1)³ as a prerequisite, it does not seem possible to draw this conclusion with complete confidence from presently available evidence.
(Gagne, 1970, p.66)

The other learning type, "chaining," appears with "verbal associations" configured as an alternate.

Gagne explains the hierarchy:

What distinguishes one form of learning from another is the initial state of the learning--in other words, its prerequisites. For example, the conditions for chaining ["connecting together, in a sequence of two or more, previously learned stimulus-response connections" (Also known as habits)] require that the individual have previously learned stimulus-response connections available to him, so that they can be chained. (Gagne, 1970, p.66)

There is, thus, a requirement for prerequisites such that the higher type of learning subsumes the lower and there is an ordering of complexity from top to bottom. But the taxonomy is disjointed. There are two major breaks between (a) the lower four ("simple and widely occurring") and higher four learning types, and (b) within the higher types, between what may now be viewed from the vantage point of 20 years after, as information processing/concept formation--"concept and rule learning"--and "problem solving." The latter terms are defined respectively as "the classification of stimulus sets in terms of abstracted properties;" "a chain of two or more concepts in operation;" and "the combination of ideas to arrive at a new idea."

Gagne himself recognizes the disjoints. "There are three types of basic [emphasis added], or associative, learning: signal, operant, and verbal associations, plus a closely allied fourth, chaining." (Gagne, 1985, p. 13). He acknowledges (1970) the presence of elements in problem solving that cannot be explained by the preceding learning types. Problem solving, as defined, reaches deep into the realm of higher-order cognitive processes, yet Gagne does not resolve the issue later. Higher order rules are merely said to "often result from the learner's thinking in a problem solving situation. In attempting to solve a particular problem, the learner may put together two or more rules from very different content domains in order

to form a higher order rule that solves the problem." (Gagne, 1985, p. 54). This sounds right as far as it goes, but it is a narrow view.

The five "outcomes of learning" are introduced (Gagne, 1984) as having been distinguished and widely accepted by the field. "No particular reason exists for thinking of these five different learning outcomes as constituting a taxonomy or as having been derived for that reason." (Gagne, 1985, p. 384).

The categories of learning are (a) intellectual skills, (b) verbal information, (c) cognitive strategies, (d) motor skills, and (e) attitudes. Gagne observes that the possession of an intellectual skill, or procedural knowledge (his paraphrase), is shown when a person is able to apply a sequence of concepts representing a condition ["If..."] and action [..., "then,..."] to a general class of situations. Procedural knowledge consists of higher-order rules, which are combinations of rules; procedures, relatively lengthy rules or rules with many steps; rules, a rule being a relation between two or more things or concepts; and concepts, which are subordinate to rules. Concepts can be analyzed into even simpler requisite skills--discrimination and generalization. Verbal information, or declarative knowledge (his paraphrase), consists of facts and domains organized in their stored form as networks or schemas. Cognitive strategies, or "executive control processes," are defined by Gagne (1985) as internally organized skills that regulate, monitor, and improve self-regulation of such internal processes as attending and selective perceiving, encoding incoming material for long-term storage, retrieval, and problem solving; e.g., constructive search, limiting the problem space, and dividing the problem into parts. Gagne's "cognitive strategies" appear to be aspects of metacognition. Motor skills and attitudes are, in essence, patailed out. "The separation of motor skills from verbal learning has a long history in psychology and is widely accepted." (Gagne, 1984, p. 384). "Attitudes" occupy an indefinite status, "a special place," and are defined as "inferred mental states" that influence and moderate persistently, consistently, and over time the choices of personal action made by the individual in a variety of specific situations. Attitudes, he notes, are generally considered to have affective and cognitive aspects. The outcomes of learning can be reduced then to information processing, deductive reasoning, and metacognition, (b),(a), and (c), respectively. And, despite Gagne's disclaimer, the outcomes of learning is a classification of human capabilities.

The two schemes are related by more than the fact, which Gagne claims, that each and every category of learned capabilities, the learning outcomes, can be achieved by the eight learning prototypes. Intellectual skills, in fact, subsume learning types five through eight, whereas verbal information is largely the outcome of verbal associations. "The elemental form of verbal information probably should be conceived as a verbal chain, in which an instance of the object is associated with its name." (Gagne, 1985, p. 61). This combination affords a cognitive skills:cognitive process relationship as shown in Figure 7.

FIGURE 7
Gagne's Learning Outcomes and Types, Integrated

METACOGNITIVE	COGNITIVE	AFFECTIVE	PSYCHO-MOTOR SKILLS
Intellectual Skills (Procedural Knowledge)	Verbal Information (Declarative Knowledge)	Attitudes	
Procedures			
	Verbal Associations		
Rules			
Concepts			
Discriminations	Generalizations		

Cattell's Triadic Theory of Cognitive Abilities. Though it appeared later (Cattell, 1971), Cattell's triadic theory of cognitive abilities belongs in that tradition of the earlier abilities theorists for whom a primary source of information was experimental, factor-analytic research on individual differences. The triadic theory is one of three in Cattell's construction of abilities. The other are temperament traits and dynamic traits (attitudes and interests). Cognitive abilities are linked via a jointly held construct, intelligence, to a structure of 16 bipolar personality factors.

In this triadic theory of cognitive abilities (Figure 8), Cattell attempts to go beyond the legacy of factor-analytic method, i.e., the "stratum model" in his words, to a so-called "reticular model," which recognizes that the abilities pursued and identified by factor analysis may operate bi-directionally and circularly. In Cattell's model, there are three components of interest: the so-called limiting capacities, or general powers; provincials, or local powers; and agencies, in essence the realization in performance of the higher-order general factors (the area of inquiry for the preliminary taxonomy being designed). These three components operate at two levels of generality. There is actually a fourth component, specific traits (or factors), operating at a third level, which Cattell explains as "an influence found only in one performance," and of little theoretical interest to him. Notable among the three components

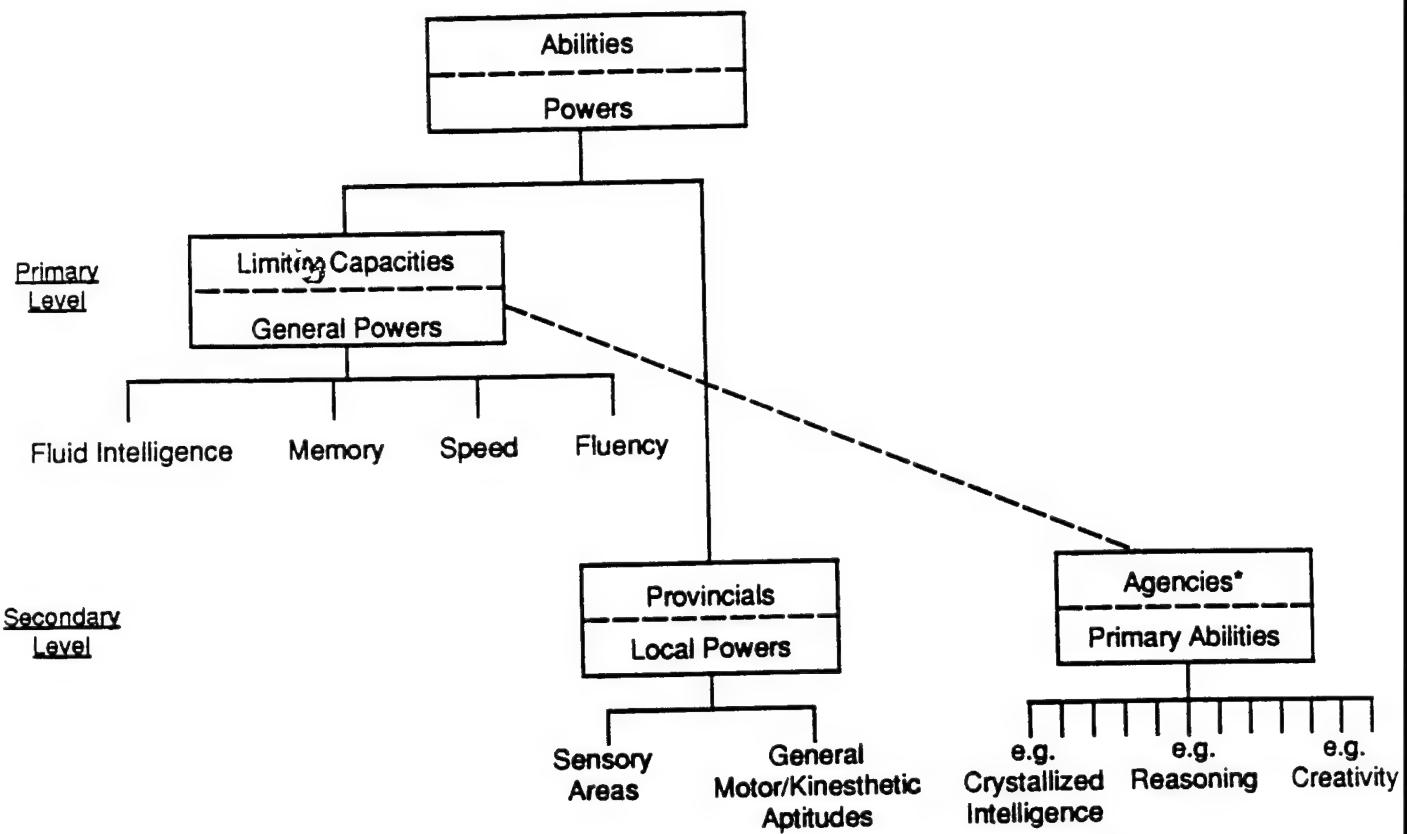


Figure 8. Cattell's Triadic Theory of Cognitive Abilities

Note: * About a dozen primary factors found from correlations of ability performances

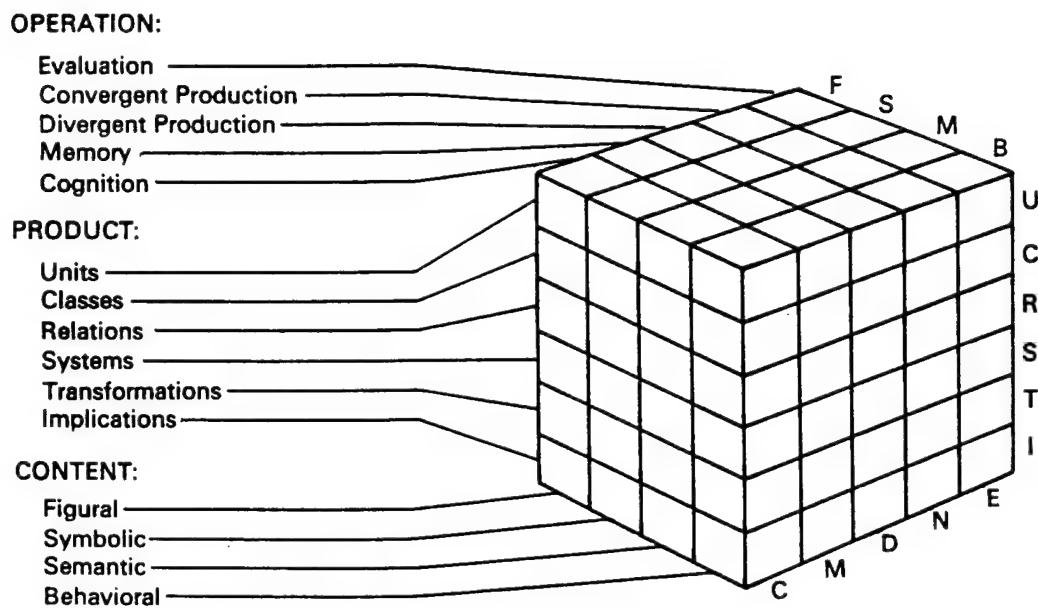


Figure 9. Guilford's Structure of the Intellect Model.

Note: From The Nature of Human Intelligence. By J. P. Guilford. Copyright 1967 by McGraw-Hill.

in Cattell's two-level hierarchy are fluid intelligence and memory, both at the higher-level, general factors; the sensory areas and general motor and kinesthetic aptitudes, among local powers, at the secondary level; and crystallized intelligence, reasoning (both inductive and deductive), and creativity, among agencies, at the secondary level.

Most fascinating is Cattell's view of intelligence, which "polarizes" into fluid and crystallized intelligence as the human being develops.

The positive correlations that tend to exist among the agencies and which is the basis of our inferring a second order a_g of crystallized general intelligence is solely due to the contribution to all of them from g (general ability, or intelligence). a_g so produced becomes a source trait, by itself a unitary influence aiding and contributing to other agencies such as g_f did earlier in the course of development. (Cattell, 1971, p. 349).

As to the relationships among IQ, g_p , and a_g , Cattell holds the IQ by a traditional test will work roughly as an index of a_g , as it is the summation of fluid ability with amount of school experience, interest, and memory.

Guilford's Structure of the Intellect Model. Guilford (1967) proposed a radically different classification. Although hierarchical models have held sway among theories of intellectual abilities and other personality traits, there are network models as well (e.g., Guttman's facet model, 1965). Guilford's structure-of-the-intellect model is a cross-classification of phenomena in intersecting, rather than categories within, categories. Guilford's three-dimensional cube identifies 120 (later, 150) hypothetical factors or abilities by the dimensions operations: evaluation, convergent production, divergent production, memory, and cognition; product: units, classes, relations, systems, transformations, implications; and content: figural, symbolic, semantic, and behavioral. (Guilford later created visual and auditory content from figural content.) More than two-thirds of the abilities are said to have emerged in factor-analytic studies.

Guilford's "a priori" classification of cognitive abilities appears in Figure 9. It is surely the most comprehensive, detailed system for describing cognitive functioning available in the psychological literature.

As Guilford puts it, "the order of the categories along each dimension of the model has some logical reasons behind it.... Cognition is basic to all other kinds of operations; hence it appears first." ... From front to back of the model there is increasing dependency of one kind of operation upon the others." (Guilford, 1967, p. 67). Certainly, cognition has been the most extensively explored operation in Guilford's own experimental work. Among products, units are regarded as basic; implications are the most complex. Guilford does not make the same pronouncement about content but devotes the most space to semantic content--or verbal information in Gagne's terminology--and offers enough explanation to afford the inference that his basic-to-complex ordering applies from figural to behavioral categories.

From these observations, one should find evaluation (highest-level operation) of implications (highest-level product) in the behavioral domain (highest-level content area) to be the highest-order intellectual ability. But these or similar conclusions do not appear, though they can surely be derived from the model itself. Interestingly enough, the intellectual ability defined by this intersect would seem paramount among abilities necessary for effective strategic leadership.

Nevertheless, if one accepts the requirement that a taxonomy ought to be predictive of phenomena, Guilford's structure-of-the-intellect model points to other intriguing possibilities. For example, in his consideration of the intersect cognition of implications, Guilford first defines implications as "close to cause-effect relationships" (1967, p. 104). He then explains that expectancies, anticipations, and predictions are emphasized by the intersect. Continuing on, he explains that, whereas in formal logic the paradigm of antecedent-consequent is locked in, implications drawn from real-world situations can only be probabilistic. As another example, from the three-way intersect of cognitive operations upon behavioral content embodied in a systems product, Guilford derives his construct of social intelligence.

In essence, Guilford's cube subsumes three major constructs historically left hanging by the discipline of psychology, but without imposing any order of priority on them. These are creative intellect (divergent production that can operate on figural, alpha-numeric, semantic, or behavioral content); social intelligence (cognition about behavioral systems); and intelligence ("cognition" plus "convergent thinking," assuming Guilford's understanding of those terms). Cognition means having information and comprehending it--"like spectator behavior." Convergent thinking, closest to logical deduction in Guilford's view, requires that the individual apply his cognitive and mnemonic abilities, as in "participant behavior" (Guilford, 1967, p. 184). The parallels between these--in fact between all of Guilford's operations and Bloom's knowledge, comprehension, and application outcomes--are virtually isomorphic, with the exception of Guilford's reversal in the divergent-convergent thinking sequence of Bloom's ordering of analysis and synthesis.

Guilford singles out the lack of research and testing capability for two abilities demarcated by his model, convergent production and evaluation, both of which he places above divergent production in his most-to-least-basic ranking.

In view of the apparent importance of convergent production abilities for any occupations in which rigorous thinking is involved--mathematics, logic, science, engineering, and law, to name a few--there is a need to push forward in the exploration of this whole area. (1967, p. 183).

Evaluation in all its aspects--absolute, relative, or disjunctive--is, in his opinion, a neglected aspect of intelligence. Psychometricians have ignored or overlooked it in part because of the operational difficulty in differentiating evaluative abilities from corresponding cognitive abilities. Indeed, evaluative tests, Guilford asserts, have often employed forms analogous to those for divergent or convergent production (1967, p. 202).

TABLE 2. Fleishman's Taxonomy of Cognitive Abilities

FLEISHMAN'S TAXONOMY OF COGNITIVE ABILITIES		
Ability Category	Ability	Description
1. LINGUISTIC	Verbal Comprehension:	Understands language, either written or spoken; to hear a description of an event and understand what happened.
	Verbal Expression:	Uses either oral or written language to communicate information or ideas to other people; includes vocabulary, knowledge of distinctions among words, and knowledge of grammar and the way words are ordered.
3. CREATIVE	Fluency of Ideas:	Produces a number of ideas about a given topic. Concerns only the <i>number</i> of ideas, not the quality.
	Originality:	Produces unusual or clever responses to a given topic or situation; to improve solutions in situations where standard operating procedures do not apply.
5. MEMORY	Memorization:	Memorizes and retains new information that occurs as a routine part of the task or jobs.
6. PROBLEM SOLVING/ REASONING	Problem Sensitivity:	Recognizes or identifies the existence of problems; involves both the recognition of the problem as a whole and the elements of the problem but does not include the ability to solve the problem.
	Deductive Reasoning:	Applies general rules or regulations to specific cases or to proceed from stated principles to logical conclusions.
	Inductive Reasoning:	Finds a rule or concept that fits the situation; would include coming up with a logical explanation for a series of events that seem to be unrelated.
9. PERCEPTION/ INFORMATION PROCESSING	Information Ordering:	Applies rules to a situation for the purpose of putting the information in the best or most appropriate sequence; involves the application of previously specified rules and procedures to a given situation.
	Category Flexibility:	Produces alternative groupings or categories for a set of things. These "things" might be people, ideas, theories.
	Spatial Orientation:	Keeps a clear idea of where one is in relation to the space one happens to be in; keeps one from getting lost in a particular space.
	Visualization:	Forms mental images of what objects look like after they have been changed or transformed in some way.
	Speed of Closure:	Involves the speed with which a large number of elements can be combined and organized in a meaningful pattern when one does not know what the pattern is or what is to be identified. Means having to combine lots of information quickly.
14.	Flexibility of Closure:	Involves the skill of finding an object that is somehow hidden in a bunch of other objects; would involve picking out a particular face in a crowd of faces. Speed not important.
15.	Selective Attention:	Completes a task in the presence of distraction or monotony.
16.	Perceptual Speed:	Involves the speed with which the features of a person, place, or thing can be compared with the features of another; determines how similar the two objects are.
17.	Time Sharing:	Pays attention to two sources of information at the same time. The information that is received from these two sources may be either combined or used separately. Important aspect is ability to deal with information that is coming <i>rapidly</i> from several different sources.

Table 3. Mumford's General KSAO Taxonomy: Cognitive Abilities

MUMFORD'S GENERAL KSAO TAXONOMY: COGNITIVE ABILITIES			
	Ability Category	Ability	Description
1.	LINGUISTIC	Oral Comprehension:	Understand the meaning of spoken words and the ideas associated with them.
2.		Oral Communication:	Communicate ideas with spoken words.
3.		Written Comprehension:	Understand written words and sentences.
4.		Written Communication:	Communicate with written words and sentences.
5.	CREATIVE	Originality:	Produce creative and effective responses related to a given topic or situation.
6.	PROBLEM SOLVING/ REASONING	Inductive Reasoning:	Use separate pieces of information to form general rules or principles.
7.		Deductive Reasoning:	Apply general rules to specific problems to come up with logical conclusions.
8.		Decision Making:	Select and evaluate possible options which lead to the solution of a problem. This includes selection of the best approach to use in reaching the decision.
9.	ATTENTION	Information Evaluation:	Assess information in order to determine whether the value of additional information is likely to be greater than the cost or effort of obtaining it.
10.		Alertness:	Maintain mental awareness and physical endurance over extended periods of time.
11.		Concentration:	Perform a task in the presence of distractions or under monotonous conditions without significant loss in efficiency.
12.		Attention to Detail:	Give careful attention to various aspects of the work; are sure that nothing is overlooked.
13.		Multiple Attention:	Shift back and forth between two or more sources of information.
14.	PROBLEM SOLVING/ REASONING	Problem Sensitivity:	Recognize difficulties before or early in their development.
15.	MEMORY	Memory:	Learn and store relevant information and selectively recall and use that which is relevant to a specific context.
16.	SPATIAL/MECHANICAL RELATIONS	Mechanical Comprehension:	Determine the functional interrelationship of parts within a mechanical system.
17.	ATTENTION	Monitoring:	Maintain an awareness of relevant indicators over a period of time, especially where they occur infrequently or against a continually changing background.

The New Arrivals

The more recent taxonomies embrace two extremes: either borrowing from earlier work in cognitive psychology (Mumford et al., 1986; from Fleishman, 1975) or from contemporaneous work in related fields (Bucy, 1989; from Jaques, 1985); or refreshing originals (Biggs and Collis, 1985; Vandendorpe, 1982). The Van Hiele taxonomy, although based on the French/Germanic view of human development, falls close to this end of the spectrum.

Fleishman's Taxonomy. "Highly regarded" as late as 1985 (Landy, 1985, p. 246), Fleishman's taxonomy (Fleishman, 1975) is a list of 17 cognitive abilities and 17 physical abilities derived from Fleishman's experimental work on human perceptual performance. The list of cognitive abilities (Table 2), which is Landy's synthesis of Fleishman's research results, is a melange of linguistic (verbal comprehension and expression); creative (fluency of ideas and originality); memory; problem solving/reasoning (problem sensitivity, deductive and inductive reasoning); and perceptual/information processing abilities. Nine of the 17 abilities fall into the last category--perceptual/information processing. This might be interpreted to mean that what is very likely information processing is the foundation for all higher generic cognitive tasks or meta processes, except that Fleishman is silent on this point. The ordering and implied rough grouping seems to be imposed by Landy.

Mumford's General KSAO Taxonomy. The model offered by Mumford (Mumford et al., 1986) attempts to specify through presentation of two taxonomies both the generic problem-solving skills and the "knowledges, skills, abilities, and other characteristics (KSAO's)" required in given military leadership positions. In fact, four lists termed "the general KSAO taxonomy"--knowledges, cognitive abilities, physical abilities, and other characteristics--have a "taxonomy of generic problem solving skills" superimposed on them with no explanation of how the components in any one of the five major elements might interrelate. The general KSAO taxonomy is said to "provide a comprehensive and general summary description of the personal characteristics likely to influence effective performance in various leadership activities." (Mumford et al., 1986, p. 10).

The taxonomy addresses the characteristics thought essential to both commissioned and noncommissioned officers. The list of cognitive abilities (Table 3) is little more than an acknowledged borrowing from Fleishman's taxonomy of 10 years earlier, which had little to do with leadership capabilities and is itself a roughly ordered melange of linguistic, creative, reasoning, memory, and information-processing skills. However, the groupings in the earlier taxonomy, imposed by Landy or not, are cleaner and fewer in number. The second, generic problem-solving taxonomy is presented by Mumford et al. in a flow diagram of an incrementalized "basic" problem-solving process and shows nothing of the metacognitive components that might justify it as the superordinate meta process it is at one point held to be. For ease of comparison, Fleishman's and Mumford's KSAO taxonomies appear as companion tables--Tables 2 and 3. The "ability category" column has been added by the author. The original order of the taxonomic elements remains.

Bucy's Quintave Typology of Reasoning (Based on Elliott Jaques' Model of Cognitive Functioning). In this typology, Bucy explores how the structure of reasoning affects moral problem solving by devising and then testing the construct validity and reliability of a scheme for classifying distinct types of reasoning. A moral problem is defined as one in which an individual faces a situation in which his or her decision will affect the well-being of others.

The typology is a four-by-four matrix consisting on the horizontal axis of so-called generic steps in problem solving and on the vertical axis of four modes of cognitive functioning. The problem-solving steps are (1) defining the situation, (2) perceiving its causation, (3) developing alternatives, and (4) selecting and justifying an alternative. The modes of reasoning are (1) shaping, (2) reflecting, (3) extrapolating, and (4) parallel processing. The modes of reasoning are drawn directly from Jaques' model, where they occur in repeating quintave hierarchies. They warrant further definition here (Jaques, 1985).

I. Shaping--uses existing sets without constructing new ones. A person employing this cognitive mode uses terms to label sets but does not identify the elements that constitute the sets. The components of the sets are implicit.

II. Reflecting--constructs unique, discrete, primary sets. A set is **unique** if it is constructed to deal with a specific situation; it is **discrete** when complete, its boundaries are closed, and it is noninteractive with other sets. It is **primary** when it is made up of specific elements.

III. Extrapolating--constructs interactive primary sets by adding sets together, breaking them up, overlapping them, or in some way allowing them to evolve over time. A decision-tree diagram reflects the structure of extrapolating with future decisions evolving out of previous decisions.

IV. Parallel processing--constructs partial secondary sets. These consist of both primary sets and elements. For example, parallel processing occurs when an individual considers the interaction of a discrete element (such as bidding on a contract) with existing secondary sets (such as ongoing operations of marketing, production, and finance.)

V. Shaping--constructs secondary sets. Secondary sets are composed solely of primary sets without access to the uncombined direct elements. These secondary sets then become the direct elements for the shaping mode of the next quintave.

Bucy's typology is said to be designed for use as part of a particular methodology and "is not for classifying reasoning which takes place outside the parameters of the methodology" [emphasis added] (Bucy, 1989, p.3). In the procedure itself, an examiner presents the subject with a written scenario containing a moral problem and asks four questions that represent the four components of the problem-solving process. Level of reasoning can thereby be classified. Bucy's typology is presented in Table 4.

TABLE 4
The Quintave Typology of Reasoning

SECTION I--RESPONSES DESCRIBING A SITUATION

Shaping:	a label without definition or specification.
Reflecting:	a label defined by one or more specific elements, or two or more specific elements defining an implied label.
Extrapolating:	a series of connected events evolving over time.
Parallel Processing:	a scenario with possible connections among multiple issues and/or events.

SECTION II--RESPONSES DESCRIBING THE CAUSE

Shaping:	a single factor in a one-step process.
Reflecting:	a single factor defined by one or more specific elements in a one-step process, or two or more specific elements defining an implied single factor in a one-step process.
Extrapolating:	a series of related factors in a multistep process.
Parallel Processing:	probable interaction among multiple processes.

SECTION III--RESPONSES DESCRIBING ALTERNATIVE ACTIONS

Shaping:	a choice of either accepting or rejecting a given action.
Reflecting:	construction of two or more specific actions.
Extrapolating:	one sequence of action with two or more choice points, or two or more unconnected alternative sequences of action.
Parallel Processing:	two or more interactive sequences of action.

SECTION IV--RESPONSES DESCRIBING SELECTION AND JUSTIFICATION

Shaping:	a single action justified by a single reason.
Reflecting:	one or more specific actions, each justified with multiple reasons.
Extrapolating:	one or more sequences of action, each with two or more choice points, each choice point justified with serially connected consequences and/or principles.
Parallel Processing:	two or more interactive action sequences, each choice justified with multiple interactive consequences and principles.

Note: From A Typology of Reasoning. By Flynn Bucy. Copyright 1989 by Dissertation Abstracts International.

Clearly, in this typology modes of reasoning are the operative parameter. The view of problem solving is so generic it is virtually powerless on its own as a heuristic. Thus, the typology borrows as much as it applies Jaques' model.

However, Bucy's data and his interpretations of them are interesting and offer implications for Jaques' theory. While the content of the typology was found to be a valid reflection of Jaques' model (and interrater reliability good, $k=.66$), most interesting is the finding, at variance with much of Jaques' work, that 68% of the subjects used at least two modes of reasoning and 28% used three or more. This phenomenon was termed the dynamic quality of cognitive functioning. Jaques has focused much of his work on identifying an individual's cognitive stratum. Thus, for example, he seems to assert that a Stratum III individual would use the extrapolating mode of reasoning, regardless of the particular problem with which he or she was confronted. However, as Bucy puts it

Following the above example, a person with cognitive power adequate to operate at Stratum III could use the extrapolating mode as well as the shaping and reflecting modes within Quintave B. This person would also be able to use all four modes of reasoning within Quintave A. (See below for definition of quintave.) (Bucy, 1989, p. 89).

Thus, incorporating the dynamic quality of cognitive functioning into Jaques' quintave model would indicate that a person could use the modes equal to or lower than his or her maximum capability, thereby redefining the model as a true cumulative, hierarchical progression.

Elliott Jaques' Model of Cognitive Functioning. Elliott Jaques' Stratified Systems Theory, of which the model addressed here is a part, attempts to define the interface between structural characteristics of bureaucracies and stratified cognitive functioning. Different functional levels in a bureaucracy, which are more or less universally operative, require different levels of cognitive capability--the higher the bureaucratic level, the more complex the requisite cognitive skills.

Central to Jaques' model of cognitive functioning are the notions of cognitive power and discontinuous changes in cognitive state, which Jaques orders into seven strata operationally defined by time-frame ranges. Cognitive power is defined as "the mental force a person can exercise in processing and organizing information and in constructing an operating reality." (Jaques, 1985, p. 107). More specifically, as Bucy says, it is "an individual's capability to create, manipulate, and interpret mental representations and incorporate them into a map of reality." (Bucy, 1989, p. 35). Cognition, according to Jaques, involves the combination of elements into meaningful patterns (Jaques, 1985, p. 111). The greater the cognitive power, the bigger, or more extensive and more complex his or her model of reality; and as cognitive power increases and reaches specific critical points, identifiable in terms of the maximum time horizon achieved, discontinuous changes in cognitive state occur.

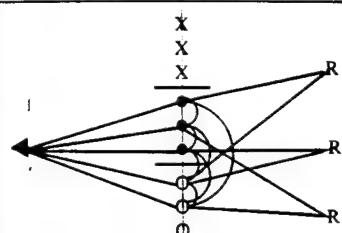
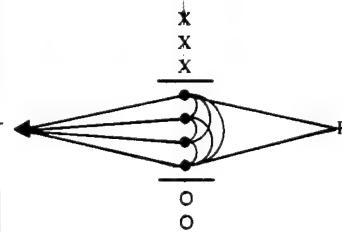
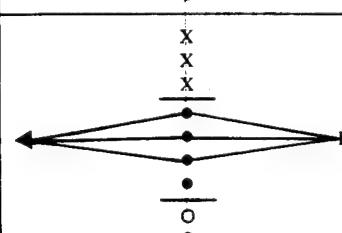
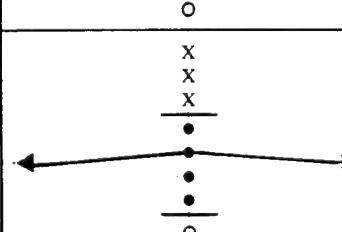
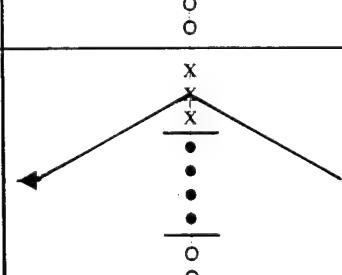
TABLE 5
Quintaves, Cognitive Strata, Cognitive Modes, and Time Frames

Quintave	Cognitive Stratum	Cognitive Mode	Time Frame
QD		Shaping	5000 years
		Parallel Processing	2000
		Extrapolating	1000
		Reflecting	500
		Shaping	200
QC		Shaping	200 years
		Parallel Processing	100
	VII	Extrapolating	50
	VI	Reflecting	20
	V	Shaping	10
QB	V	Shaping	10 years
	IV	Parallel Processing	5
	III	Extrapolating	2
	II	Reflecting	1
	I	Shaping	3 months
QA		Shaping	3 months
		Parallel Processing	1 day
		Extrapolating	10 hours
		Reflecting	5 hours
		Shaping	1 hour

Table 6. The Solo Taxonomy

THE SOLO TAXONOMY

Base Stage of "Cognitive Development and Response Description"

Developmental base stage with minimal age	SOLO description of Response	“CRUCIAL CHARACTERISTICS”			4 Response Structure
		(Working Memory) Capacity	(Internal Reasoning) Process Relating operation	(Learner Felt Needs) Consistency and closure	
Formal Operations (16+ years)	Extended Abstract	<i>Maximal:</i> cue + relevant data + interrelations + hypotheses	Deduction and induction. Can generalize to situations not experienced	Inconsistencies resolved. No felt need to give closed decisions—conclusions held open, or qualified to allow logically possible alternatives. (R ₁ , R ₂ , R ₃)	
Concrete Generalization (13-15 years)	Relational (Abstract)	<i>High:</i> cue + relevant data + interrelations	Induction. Can generalize within given or experienced context using related aspects	No inconsistency within the given system, but since closure is unique so inconsistencies may occur when he goes outside the system	
Middle Concrete (10-12 years)	Multistructural (Second order concrete components)	<i>Medium:</i> cue + isolated relevant data	Can “generalize” only in terms of a few limited and independent aspects	Although has a feeling for consistency can be inconsistent because closes too soon on basis of isolated fixations on data, and so can come to different conclusions with same data	
Early Concrete (7-9 years)	Unistructural (First order concrete components)	<i>Low:</i> cue + one relevant datum	Can “generalize” only in terms of one aspect	No felt need for consistency, thus closes too quickly: jumps to conclusions on one aspect, and so can be very inconsistent	
Pre-operational (4-6 years)	Prestructural (First order concrete components)	<i>Minimal:</i> cue and response confused	Denial, tautology, transduction. Bound to specifics	No felt need for consistency. Closes without even seeing the problem	

⁴ Kinds of data used: X = irrelevant or inappropriate; ● = related and given in display; O = related and hypothetical, not given.

Distinctive structures of cognitive functioning characterize each of the seven strata. These are described in Jaques' quintave hierarchy of four distinct modes of thinking--each representing a structural change in level of cognitive abstraction. He defines the four modes in terms of an individual's ability to construct different kinds of conceptual sets, where sets are groupings of elements or basic units (p. 33, this report, for specific definitions). Jaques asserts that these four cognitive modes occur in five-part patterns. Like the octave of the musical scale where C is the first and the last note, the first mode of a quintave hierarchy reappears as the last (Jaques, 1985, p. 114). In fact, the discontinuous changes in cognitive strata are supposed to occur because of changes in cognitive mode. It is important to note that the so-called quintave hierarchies of cognitive modes duplicate in successively higher levels of cognitive task complexity called quintaves. The relationships among quintaves, cognitive strata (which relate most directly to Jaques' view of bureaucratic structure), and cognitive modes, with their defining time frames, appear in Table 5, adapted from Bucy (1989, p. 45).

Quintave A (QA) is said to characterize the tasks taken up by children; Quintaves B and C (QB and QC) characterize those by adults. Quintave D (QD) is speculative but said to address the level of complexity needed for building and maintaining whole societies. QC incorporates the tasks necessary for leadership of large organizations, whereas QB is said to capture the normal range of adult functioning. Although Jaques has not observed anyone performing at a Quintave D level, he does think it may exist and that some individuals such as mystics and religious messiahs may actually operate with a time frame extending hundreds or thousands of years into the future. (Jaques, 1985, p. 124).

The Biggs and Collis SOLO Taxonomy and Extended SOLO Model. The **SOLO** taxonomy, Structure of the Observed Learning Outcome, is directed to the structural complexity of a learner's response and features a five-level cumulative hierarchy originally designed to help teachers evaluate the quality of student learning. The levels are explicitly equated to the Piagetian stages of development as follows: prestructural (preoperational stage); unistructural (early concrete); multistructural (middle concrete); relational (concrete generalization); and extended abstract (formal operations). The levels are ordered in terms of characteristics that include progression from concrete to abstract; an increasing number of organizing dimensions; and increasing consistency in use of the organizing (or relating) principles, with hypothetical or self-generated principles being used at the most complex end. Four main dimensions are used to categorize responses: (1) working memory capacity, (2) operations relating task content with cue or question, (3) response consistency within a response, and relative necessity for closure in making that response, and (4) general overall response structure that results from the interaction of the previous dimensions. Table 6 presents the **SOLO** taxonomy.

Here, as in several taxonomies presented earlier, the intervals between levels are unequal. There is a bigger leap in terms of the cognitive processes used in moving from the unistructural to the multistructural level than from the previous "barrier" between prestructural and unistructural levels ["from irrelevance to relevance"]. Similarly, the

Table 7. The Extended Solo Model

THE EXTENDED SOLO MODEL			Examples of extended abstract functioning by mode	
1 Mode of functioning (Developmental stage)	2 Structure of response (Learning cycle)		Conservation	Symbolism
Sensorimotor	Unistructural Multistructural Relational	= Prestructural		
Intuitive	Extended abstract *Prestructural	= Unistructural = Multistructural = Relational	Objects	Words
Concrete	*Unistructural *Multistructural *Relational	= Extended abstract = Prestructural	Classes	Sentences
Formal—1st order	*Extended abstract Prestructural	= Unistructural = Multistructural = Relational	Systems	Propositions
Formal—2nd order	Unistructural Multistructural Relational	= Extended abstract = Prestructural	Theories (of increasingly higher order)	Propositions (of increasingly higher order)
Formal—3rd order etc.	Extended abstract	= Unistructural = Multistructural = Relational, etc.		

Note: From Evaluating the Quality of Learning. By John B. Biggs and Kevin F. Collis.
Copyright 1982 by Academic Press.

authors continue, there is a distinct leap in terms of underlying processes between entertaining unrelated aspects, no matter how many, and relating them.

A major catalyst for the development of **SOLO** was its authors' belief that qualitative aspects of evaluating learning have not been researched or applied to nearly the same extent as quantitative ones and in practice are highly subjective and poorly integrated into grading procedures. Biggs and Collis single out Bloom's taxonomy, which, in practice, has been used most in the construction of test items. The **SOLO** taxonomy was therefore designed to provide a structure to help teachers make judgments about the quality of learning that takes place in the classroom.

Although the initial impetus was the practical issue of evaluating quality of learning, the taxonomy has become a very different model. Even at the outset, the taxonomy was set against a backdrop of hypothetical cognitive structures (HCS). These are said to be generalized and not directly measurable, as opposed to the structures of actual responses given to specific learning tasks. There are thus HCS stages, best represented by the developmental stages and **SOLO** level dimensions of the taxonomy. This distinction is analogous, in the authors' opinion, to that between ability and attainment, which is exteriorized. HCS is also said to be like IQ in that it is relatively stable and not directly dependent upon instruction.

In addition, there is a clear shift from emphasis on learned responses to emphasis on the psychological processes underlying the obtained responses. On the basis of a factor analysis of **SOLO** ratings of given task performances and of other scores (including those from tests designed to measure reasoning processes, for example, the Raven Progressive Matrices Test), **SOLO** measured critical cognitive processes, namely simultaneous (also termed reasoning) and, to some extent, successive (also termed memory) synthesis. While validation efforts are still preliminary, such results are promising.

Additional research (one-way analyses of variance) indicated that simultaneous processing significantly discriminates relational from multistructural responses and multistructural from unistructural responses, whereas sequential processing moves from unistructural to multistructural but not in the multistructural-relational transition.

In a second shift (this in the structural and conceptual configuration of the taxonomy), Biggs and Collis move to what they term the **Extended SOLO Model**, characterized as a learning-development model in which both level of learning qua learning cycle and mode of functioning qua developmental stage are represented. See Table 7.

In the extended model, learning cycles from simple to complex "are implicit" within each of the now six modes of cognitive functioning, thus "marrying" the cyclical nature of learning and the hierarchical nature of cognitive development. Although the theoretical justification is hardly discernible, Biggs and Collis give some nice examples of how this conceptual revision in their model might work in reality. One example is given here for purposes of illustration.

An undergraduate enters university almost certainly operating in the first formal mode in some of his subjects. In some, he will progress to his senior year, and graduate, having extended his particular content knowledge but likely not attaining much more, in **SOLO** terms, than multistructural-formal. He has a formal understanding of several principles, but has not integrated them into a comprehensive conceptual framework for understanding the discipline in question, as a discipline. Indeed, in many instances he is not required to do so. For example, depending upon the way courses in freshman psychology are treated, the introductions to the material might be in the concrete mode with unistructural-formal or multistructural-formal outcomes at the end of the course unit. Thus, in "Learning," he might understand the principles of operant conditioning and those of classical conditioning, such that he can, for example, show how through classical conditioning an animal can become conditioned to fear a particular stimulus (unistructural-first-order formal for that context). He might then learn the escape learning paradigm whereby through operant (instrumental) conditioning an animal can operate a catch to escape. Integrating those two he might then reach a relational-first order formal level which explains the joint operation of the two principles, as in the avoidance learning paradigm.

All this is still within the first-order formal mode. The components of both sets of conditioning are still held separate from each other: one is classical, the other instrumental. However, he might then look at the concept of motivation, which to this point is a separate universe from learning. A problem arises: In the application to human behavior, both classical and operant paradigms seem to be involved in getting people to do or not to do things. People do not appear to be learning, so much as being motivated. Such a realization probably involves the first step toward a transition from the first-order to the second-order formal modes. The student is questioning now the bases of his first-order formal concepts and trying to see their superordinate relationships.

In fact, it is not usually until graduate school that a student begins to question the encapsulation surrounding his first-order learning and tries to reintegrate them at a new level. That integration may prompt new questions at a second-order level which in turn may suggest hypotheses (a transition in mode) and a research study designed to test them. By now, he is operating in the third-order formal mode for that context of study[Emphasis added]. (Biggs and Collis, 1982, p. 224).

In comparison to the present effort to construct a taxonomy, the **SOLO** taxonomy/model deals with a narrow slice of cognitive processing, namely, the skills of generalization, induction, and deduction (put to test as "simultaneous synthesis") and their interactive combination. Though, strictly speaking, a partonomy, this finely grained analytic tool also provides a sophisticated way to regard sequential and progressive human development, not as much from the standpoint of juvenile development and education, from

TABLE 8
The Five Levels of Thought by Van Hiele

Level 0--The Visual Level. Figures are recognized by their global appearance and differentiated from a context.

Level 1--The Descriptive Level. Properties of figures are analyzed on the basis of discriminated features.

Level 2--The Theoretical Level. Figures and their properties are related.

Level 3--The Level of Formal Logic. Sequences of deductive statements are developed.

Level 4--The Level of Logical Laws. Various deductive systems are analyzed rigorously and properties of deductive systems such as consistency, completeness, and independence are understood.

Note: Descriptions for Levels 0 through 4 are adapted from Hoffer (1983, p. 207) and are in agreement with the characterizations offered by Van Hiele (1986).

which it emanated, as from the degree of complexity represented, thereby offering a means to evaluate possible sources of error and decrement in adult performance and to improve the quality of instructional intervention.

Van Hiele Levels of Thought and Learning. The Van Hiele Model (1986) casts human thought as both a hierarchy and a developmental sequence of five levels, each with selected properties. In fact, these levels of thought make up only one of three major elements in the model; the other two are phases of learning, of which there are five, and insight. The model postulates that, for each level of thought, one must spin through the five learning-instructional phases to produce the insight required in the next higher level. The model emanates from Van Hiele's experience and reflection upon his work as a high school mathematics teacher in The Netherlands. His research has attracted followings in the educational and scientific establishments of the United States, the Soviet Union, and Europe. For the sake of clarity, the five levels of thought (Table 8), five phases of learning (Table 9), and insight (in text) are briefly characterized.

To move students from one thought level to the next in a subject, a sequence of five phases of learning is postulated. These are, however, more like classifications of a dynamic

TABLE 9
The Five Phases of Learning by Van Hiele

Phase 1--Inquiry

The instructor is supposed to engage students in conversation about the objects of study. The purposes of this engagement are diagnostic, instructive, and mnemonic in that the instructor learns and evaluates how the students interpret terminology, introduces the students to the topic to be examined, and sets the stage for future work.

Phase 2--Directed Orientation
(CF: Montessori Method)

The teacher sequences activities for student exploration by which students begin to realize the direction of study and to become familiar with the characteristic structures. Many of the activities are one-step tasks designed to elicit specific responses.

Phase 3--Explication

Building from previous experiences and with minimal prompting by the teacher, students refine their use of terminology and express opinions about the inherent structures of the subject matter. Students begin to form the system of relations of the subject matter.

Phase 4--Free Orientation
(CF: Problem-Solving Curricula)

Students encounter multistep tasks or tasks that can be completed in different ways. They gain experience in resolving the tasks or in finding their own way. By orienting themselves in the field under investigation, many of the relations among the objects of study become explicit to the students. [Analogous to Jaques' (1985) extrapolating, without the time dimension, and to Biggs and Collis' (1982) relational (abstract)].

Phase 5--Integration

Students review the methods at their disposal and can form an overview. The objects and relations are unified and internalized into a new domain of thought. The instructor aids this process by providing global surveys of what the students already know, taking care not to present new or discordant ideas. [Analogous to Jaques' (1985) parallel processing, and to Biggs and Collis' (1982) Extended Abstract].

Note: Descriptions for Phases 2 through 5 are essentially those of Hoffer (1983, p. 208) and are in agreement with the characterizations offered by Van Hiele (1986).

instructional-learning interaction than descriptions of learning per se. For example, in Phase 1, Inquiry, the instructor is supposed to engage students in conversation about the objects of study. The purposes of this engagement are diagnostic, instructive, and mnemonic in that the instructor learns and evaluates how the students interpret terminology, introduces the students to the topic to be examined, and sets the stage for future work. By the end of the fifth phase, a new level of thought should have been achieved.

The phases of learning are described in Table 9. According to the model, the objects and morphisms (relations) at Level_{n-1} are after Phase 5 interpreted and understood qua objects at Level_n. What is implicit at Level_{n-1} becomes explicit to the student at Level_n.

Finally, the model holds that to show insight individuals must perform correctly, adequately, deliberately, and consciously in unfamiliar situations. They must understand what they are doing, and why and when to do it. This is not, therefore, the so-called moment of insight in a creative process achieved largely through intuitive processes.

There are certain obvious limitations to the Van Hiele model for application to taxonomies of adult cognition. First, the model is quite tied to student behaviors and thought in learning geometry and, second, it is clearly directed toward juvenile instruction. It is, moreover, plainly influenced by Piagetian theory on cognitive development in that the stages or levels of thought are discontinuous, although not impervious to instructional intervention or, for that matter, incidental learning. (Van Hiele gives us this in a brief aside.) Nevertheless, the five levels of thought are useful as descriptive frames of reference, although they might better serve as prescriptions for research and instruction rather than as a labeling and categorization system for people. This hierarchy is held together by a progression from concrete (level 0) to 3rd-order abstraction (level 4). The phases of learning, too, depict a fine progression (from instructor to student control over the learning process), reveal their author's thorough grounding in pedagogy, and show considerable understanding of the learning-instructional dynamic. Perhaps the major problem with the model as devised to date--a problem that pertains to the Extended SOLO Model as well--is that the five levels of thought are not integrated with the five phases of instruction-learning except that all phases of learning are embedded in every postulated level of thought. It would be useful to know, for example, whether or not one particular method of instruction is considered more effective for fostering and developing a particular level of thought than are the others. However, the model does not as yet capture this degree of integration.

The Vandendorpe k-d Tree for Human Cognition. Originally explored in computer research, the k-d tree (Bentley, 1975) has more recently been proposed (Vandendorpe, 1985) as a model for describing human cognition, particularly the processes of memory and forgetting as well as those of convergent and divergent thinking and decision making. The model is binary and hierarchical, with multiple associate terms. In fact, for human memory retrieval, two basic models have been put forth over the years, just as they have been for human cognition: networks, of which Anderson's ACT theory (1976) is probably the most well known, and hierarchies, which, according to Vandendorpe (p. 8), are demonstrably more efficient data structures for computer retrieval and storage of data.

The model holds that incoming information is categorized and stored in the context of preceding information in that every node of the tree may order the information stored below it. The addition of new information can be effected with or without reorganization of existing information. Adding information to the tree without an attempt to reorganize it is analogous to assimilation in Piagetian terms (Piaget, 1954). Continued additions of this type can produce a state of unbalance, or disequilibrium, whereupon the knowledge base, or more often a section of it, must be rebalanced at the expense of time and energy, the data recategorized, and accommodation reached. The resorting of a portion of the tree, which Vandendorpe claims takes place "fairly often," is analogous to Piagetian decalage.

In truth, Vandendorpe's reinterpretation of Piaget's stage model of cognitive development in information-processing terms is compelling, although her point about formal operations seems inaccurate.

Piaget's conception of cognitive stages of development seems logically to parallel the idea of rebalancing the entire tree. The concrete operational stage seems particularly to represent the completely rebalanced tree that results in an integrated hierarchical structure. In that period, children are able to understand sets and subset memberships. Formal operations as a stage may not necessitate a total rebalancing; rather, it might be that formal operations require the addition of a level of hypothesizing at the top of the tree rather than a reorganization at the bottom. (Vandendorpe, 1985, p. 10).

Vandendorpe goes on to say that, when the tree is being rebalanced, information is more vulnerable in that interruption (inhibition) may cause the loss of already stored information, although not its destruction. This approaches the retrieval failure interpretation of forgetting, more typically used, however, to account for short-term memory failure. In addition, Vandendorpe suggests that such comprehensive restructuring may occur during REM sleep if one assumes that the bulk of information assimilation occurs during the waking state. This argues very favorably for situations that favor reverie, day dreaming, free association, and in general the reduction of normal strictures, individual or social, on thought.

Convergent thinking is explained prima facie by the model as a top-down search of the tree, which Vandendorpe characterizes as the "typical" search mode. If correct choices are made at all the nodes, the correct answer is retrieved. This explanation, of course, begs the role of the use of incoming information in a fluid situation.

The explanation of divergent thinking using three possible processes vis-à-vis the model is intriguing: (a) the individual accesses the tree in the typical top-down manner, reaches one appropriate conclusion but reaccesses the hierarchy, making different decisions at some nodes; (b) the referent nodes along the path to the first conclusion are used to access the tree in a horizontal reference pattern, allowing both bottom-up and top-down search; and (c) divergent thinking is the process of resorting and recategorizing. The need for an incubation period in the creative process would seem to recommend the latter process, although it is not obvious why option (b) would be ruled out.

Finally, Vandendorpe admits the possibility of several trees into her model of human information processing--a principal tree and several smaller, allied ones. Semantic, episodic, and daily memory trees may share only the initial root or be entirely unrelated structurally, although the method of storage and retrieval of data would be similar.

Cast as a hierarchical model for information processing, Vandendorpe's **k-d tree** works. But as a model of human cognition in which elements must be configured in a

FIGURE 10

Nickerson's Implied Taxonomy of Higher-Order Thought

INTELLIGENCE	CREATIVE THINKING
Critical Thinking	Metacognition
Reasoning Ability	Problem solving
Analysis	Deduction

principled fashion, it falls short. In the arena of models for human cognition, the k-d tree remains an intriguing typology.

The Also-Rans

Nickerson's Implied Taxonomy of Higher-Order Thought. Nickerson (1990, p. 11) has in fact identified as "higher order cognitive skills" "reasoning, problem solving, decision making, planning, composing [creativity, almost certainly], evaluating, learning" in that order, although he has not devised a taxonomy for them. Earlier, Nickerson (1986; Nickerson et al., 1985) asserted aspects of thinking, "problem solving, creativity and metacognition," that have "attracted the most attention." At one point (1985), he relates the three so clearly that the configuration into a model can be readily deduced.

The ability to look at things in new and unconventional ways is undoubtedly an important problem-solving skill.... Given that creativity is such an important aspect of problem solving, it might seem inappropriate to discuss the two concepts separately. But a similar point might be made with respect to most of the major concepts on which we are focusing: reasoning ability is an important determinant of problem solving ability, as is metacognition, and all three relate closely to the concept of intelligence.... However,...the ability to reason and to solve problems requiring analysis and deduction...critical thinking...are generally considered highly correlated with intelligence, [whereas] high intelligence, at least as it is represented by conventional test results [emphasis added], does not guarantee unusual creativity. Moreover,...most investigators who have made a distinction between critical and creative thinking would consider the former to be

more likely to be improvable by training than the latter. So, the notion of creativity deserves some focused attention.... It would seem that critical thinking is a necessary but not sufficient condition for creative thinking. (Nickerson, 1985, p. 84).

The construction in Figure 10 can be derived. Nickerson is clearly defining intelligence here as everything but creative thinking. His position is by no means solidly backed by the rest of the field. As Jensen (1987) points out, **intelligence** has mainly three different meanings, each exclusively favored by different psychologists. "Some regard intelligence as the sum total of all mental abilities, or as the entire repertoire of a person's knowledge and skills at a given time. Others equate intelligence with *g*, or the more general factor common to all mental abilities. The contextualists claim that what any particular culture means by intelligence is only a selection of certain abilities from the entire cognitive domain, those particularly valued by the dominant culture." Nickerson appears to be on the fringe of the first camp; Jensen, part of the second⁴.

Martinelli's Taxonomy Unjustified. Though he does not label it as such, Martinelli (1987) presents a taxonomy of cognition and metacognition similar in three of its basic elements to the preliminary taxonomy of cognition and metacognition being developed as part of this research program. His taxonomy consists of metacognition, which surrounds the entire set of processes, and four sets of partially and inconsistently elaborated cognitive skills: problem solving, which includes decision making and decision implementation; critical thinking and creativity, which are "adjacent"; and thinking and reasoning skills, which include the usual list of skills: observation, classification, inference, deductive and inductive reasoning, analysis, and synthesis. The ordering is so consistent with that in the balance of the literature that it is probably deliberate. Martinelli presents his view of cognitive skills as a "progression of critical thinking skills from least to most difficult." The taxonomy implied in his descriptions is graphically represented in Figure 11.

In close paraphrase of his words

At the bottom of the hierarchy is the general category of thinking and reasoning skills, what Sternberg and Baron (1985) call knowledge acquisition components and Robert Ennis (1985) calls basic abilities. At the next level are critical thinking--"the attempt to clarify meaning through the evaluation of evidence. Judgments are made on the basis of reasons."--and creativity, which "emphasizes divergent thinking." Problem solving is "the highest order skill" because, in solving problems, all thinking skills, including critical thinking and creativity, can be used, and complex problem solving usually involves a mix of rational and creative processes. [Emphasis added. Note the addition of a term here.] (Martinelli, 1987, p. 21).

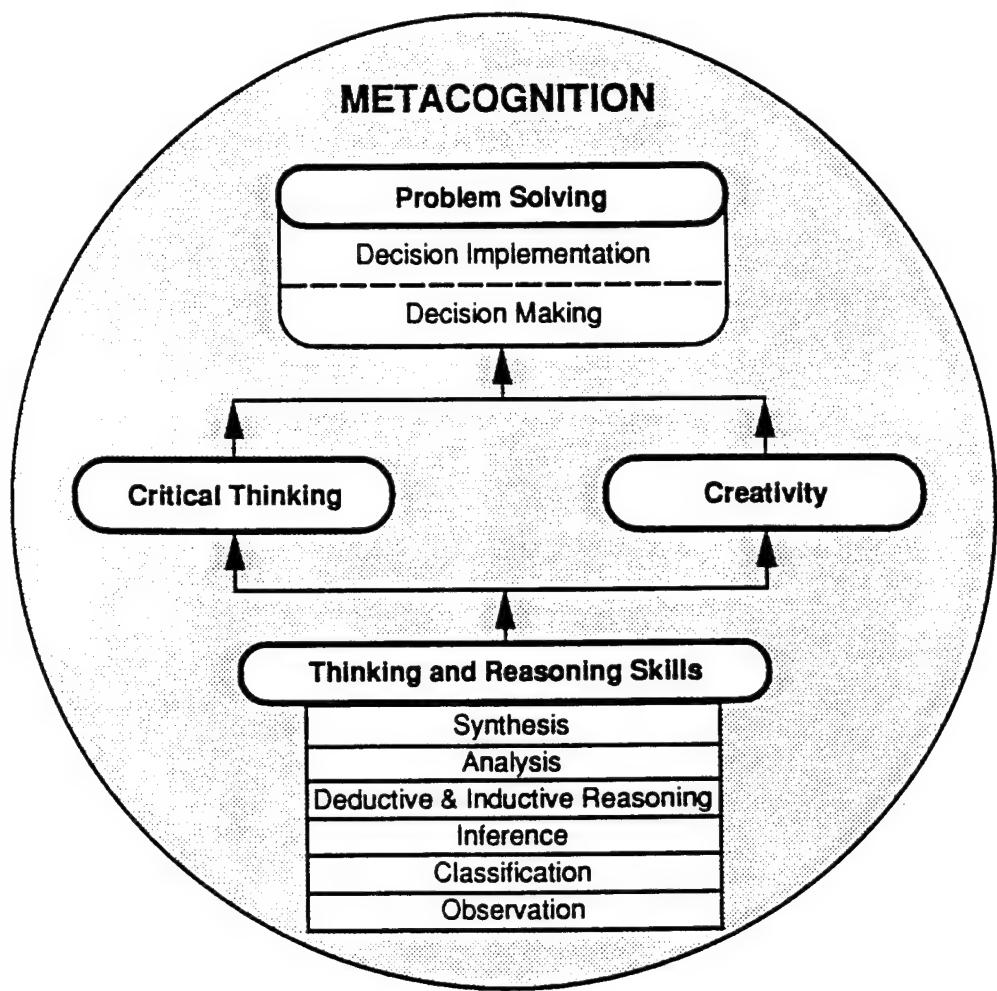


Figure 11. Martinelli's Taxonomy Unjustified

Martinelli is quite clear about his definitions and his sense of order for the four sets of cognitive skills posited. But he does not justify the order, other than to say it is an order of difficulty, which he presumably has deduced from the literature. Nor does he express the principle or principles by which the order of difficulty is derived. In particular, his incompletely specified definition of problem solving will not do either on its own or as a rationale for placing the skill at the top of the taxonomy. Martinelli's problem solving is more like generic problem solving (p. 63, this report) and his "complex problem solving" sounds like creative thinking, defined herein.

Sternberg's Three Sets of Intelligence and an Earlier Outline of Mental Abilities.

Despite the wealth of learned articles launched by R. M. Sternberg over the past decade on the topic of a theory of mental abilities (Sternberg, 1979, through Sternberg, 1989), he has not by the definition herein created a taxonomy of cognitive skills or mental abilities. In his most recent view of intelligence (Sternberg, 1987; 1989), he identifies three kinds of intelligence: social intelligence, elsewhere known as "street smarts"; analytic intelligence, the kind measured by intelligence tests like the WAIS and the Stanford-Binet; and creative intellect. He constructs de facto ordinal scales of good, better, best for these and most, fewer, few, such that creative intellect, the "best" kind to have, is possessed by only a relative few, implying a pyramidal construction (Figure 12). Perhaps the implied theoretical structure's greatest value is that it explicitly pulls the construct of creativity into the realm of intelligence.

FIGURE 12

Sternberg's Three Sets of Intelligence

Creative Intellect

Analytic Intelligence

Social Intelligence

However, Sternberg's scales are neither sequential and progressive nor hierarchical. One may acquire social intelligence before analytic intelligence (the sensorimotor stage precedes concrete operations according to Piaget's theory of human development), but the availability and emergence of creative intellect in sequence with analytic intelligence is nowhere ordained in the literature of the behavioral sciences. Moreover, one may have analytic intelligence without social intelligence; if one possesses a creative intellect, one is

STERNBERG'S OUTLINE OF A THEORY OF MENTAL ABILITIES

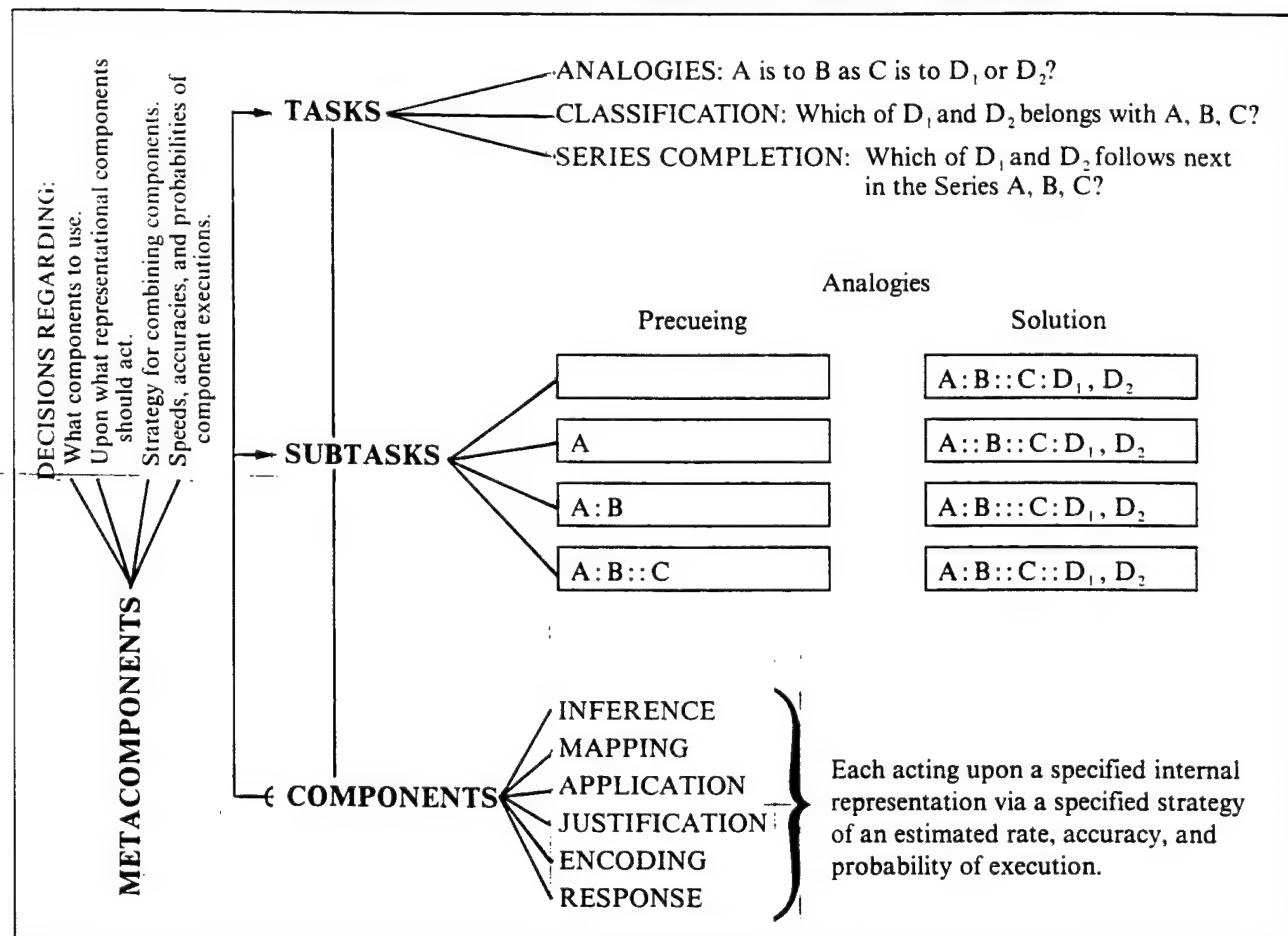


Figure 13.

Note: Examples appear to the right in the figure.

Reproduced from "The Nature of Mental Abilities." By R. M. Sternberg. March 1979. American Psychologist, p. 277.

FIGURE 13. Sternberg's Outline of a Theory of Mental Abilities

not necessarily analytic and "street smart." In other words, the "better" elements do not presuppose the others. This is consistent with popular notions of intelligence and some observational data. For example, Albert Einstein, perhaps the foremost creative mathematician and physicist of the 20th century, was said to require the assistance of graduate student escorts to cross a road. Preoccupied intellectually, the hearsay goes, he was almost totally inattentive to his surroundings.

Terman (1925), on the other hand, found in his enormous longitudinal studies of genius that individuals who scored two or more standard deviations above the mean on intelligence tests--were highly endowed with analytic intelligence--were, for the most part, creative, socially intelligent, and generally regarded in later life as highly successful. These individuals were in the top one or two percent of the population in measured IQ.

In earlier work (1979), Sternberg structured an "outline of a theory of mental abilities" as a more conventional hierarchical organization of components. The task "analogies," for example, has several subtasks; certain components--inference, mapping, application, justification, encoding, and response; and certain metacomponents (Figure 13). Sternberg clearly adopts the stance that certain cognitive processes may be tasks. He then defines the tasks as major and minor components (subtasks and components) and also requires certain related elements of metacognition. Analogies, in this case, are a type of inductive inference prescribed in a laboratory. What Sternberg appears to be offering is not so much a theory of mental abilities as an outline of the essential elements in any construction about the human mind and a hypothesis about the construction of a particular type of mental process that had engaged him experimentally--inductive inference. In the final analysis, Sternberg, in a brief apologia for the sparseness of his construct, writes: "It should be emphasized that the componential theories and models of task performance that my collaborators and I have proposed are not and are not intended to be 'true' theories and models that represent the full richness and complexity of human information processing." (Sternberg, 1979, p. 225).

SYNTHESIS AND SUMMATION

This comprehensive review is held to have yielded all relevant taxonomies of cognition in the empirical literature. Approximately 1,500 references and abstracts were scanned and about 200 documents appraised to cull the 20 theories, models, and taxonomies by 18 theoreticians and research scientists reviewed herein. A major analytic technique used in interpreting the work by a particular theorist was to aggregate continuously the concepts about cognitive process put forth, interweaving them where possible, while searching for contradictions and discrepancies. Certain conclusions are inescapable.

The scientific work on a theory of human mental abilities swings from the attempts during the first half of the 20th century to formulate comprehensive theories to attempts during the closing decades to concentrate on constructing pieces of this puzzle accurately and, from the pieces, to compose a sounder model. Viewed in the aggregate, the work is

diverse, complex, and convoluted. Viewed one by one, the models retrieved from the literature are roughly hewn. Regrettably, most do not consider anything but one-directional relationships among principal cognitive elements and, except for Cattell's triadic theory, none attempt to deal with interactive dynamic relationships seriously.

Moreover, on the matter of a theory of human mental abilities, the field is in disarray, with perhaps even more fragmentation now than during the first half of the century. There are at least five distinct theoretical groups and possibly two more. The five groups are

(1) Comprehensive composite models: These are models that are both theoretical and statistical (factor-analytically derived) in nature; e.g., Spearman, Vernon, Burt, Cattell, and Guilford. All but Guilford's are hierarchical in structure.

(2) Network models: Guilford's cube is one.

(3) Simply determined hierarchical taxonomies: Learning theorists and educators, e.g., Bloom, Gagne (1970), Nickerson, and Martinelli, have created these.

(4) "Cognitive structural" variants on the hierarchical scheme: The cognitive structural approach classifies qualitatively distinct types of reasoning operationally defined by different modes or patterns of cognitive functioning. In the models reviewed, a fixed set of levels organized on one dimension--for example, learning types--is infix'd recursively within each of a number of other, usually progressively higher, levels; e.g., Gagne (1984, 1985: The Learning Outcomes Typology); Van Hiele (Levels of Thought and Levels of Learning); Biggs and Collis (The Extended SOLO Model, levels of learning responses implanted within cognitive modes); Bucy (levels of abstraction within a typology of problem-solving steps); and Jaques (levels of abstraction within cognitive modes ranged against other levels). This may be a preferred model of cognition for the 1980s and 1990s; it is surely one to watch.

(5) Typologies of cognition: Three such typologies were reviewed here: Sternberg (1989), Mumford et al. (1986), and Fleishman (1975). These were included because the latter two are in fact referenced as taxonomies and they all are on the edge of the definition of taxonomy adopted here, recognizing that such classification schemes are acceptable per se in, for example, the biological sciences.

There are also two outliers.

(6) An information processing model by Vandendorpe, and

(7) A cognitive task-analysis model by Sternberg (1979, apparently later abandoned).

The models were examined with an eye to their underlying logic to determine whether one kind might seem more useful than the others or if any principles of construction are preferable. Although a hierarchical model of cognitive skills is the order of the day simply

by the weight of the evidence in its favor, the examples of this taxonomic type are so simplistic there is no way to decide convincingly that the hierarchical type is the best configuration to use to relate and integrate the so-called powers of the mind. Some combination may be in order, for example, of model types 2, 3, 6, and 7.

Again considering the aggregate, the yield has been scant on several counts. First, the scientific community still does not have a widely accepted, comprehensive theory of cognition in any theoretical or biological, reductionist sense. Nor does it have a general theory of learning that allows, in Fleishman's words (Fleishman, 1975), "dependable generalizations of learning principles to particular classes of tasks." Nor does it have a consensus on the concept of intelligence. According to Jensen (1987), the field of psychology has as many different conceptions of intelligence as there are experts and this is as true today as it was when the question was put to a group of experts at a professional conference in 1921. Above and beyond those circumstances, one gets no sense whatsoever of any joint sense of purpose guiding the development of these models of cognition. In other words, the field of inquiry is more paradigm- than theory-driven.

What are we to make of all this? Can any order be brought to it, granting that the 20 models identified are in some sense precursors to or representative of the state of the art? First, there is a pattern of progression across time among the models. Initially comprehensive, the focus narrowed and in the past decade has become more finely tuned, if not broader again. In fact, some cohesion is emerging, represented by two groups: (1) the (learning) cycles in the cognition stages models of Biggs and Collis, Bucy, Jaques, Van Hiele, and Gagne, and (2) the comprehensive but shallow models of Sternberg, Nickerson, and Martinelli, which are grounded in the traditions of psychometric and abilities theorists.

More important, there are intersects and there is consensus on some points, in particular the focus on cognition. Certainly, the overall terrain has been staked out. First, as Gagne (1985) notes, there has been a long-standing separation of cognitive abilities from motor abilities and personality factors, one that harks back to Burt's general factor *g*, which opposed psychomotor abilities, and Vernon's *g*, which opposed his X, or everything else, factor. Even the taxonomies of Fleishman and Mumford maintain the distinction. Second, despite the focus on cognition, a number of models recognize and attempt linkages to other aspects of the psyche. The area of beliefs, attitudes, and values has been a remarkable sticking point. Bloom linked evaluation, the highest-order intellectual skill in his taxonomy, inescapably to individual value systems. Cattell recognized the continuing and interactive influence of attitudes on intellectual and overt behavior. But only Gagne among the 11 theorists working in the past decade continues to maintain attitudes as an important construct. He identifies attitudes as one of five major learning outcomes, also recognizing its likely influence upon other cognitive processes. Third, there is general agreement on the major differentiation between alpha-numeric reasoning and perceptual-mechanical abilities first laid down by Burt and Vernon (cf. Vernon's *v:ed :: k:m* separation) and now represented in the research on right and left hemispheric specializations in the human brain. Could the factor-analytic method somehow have accessed the more neurophysiologically based aspects of

cognition? Fourth, it is probably safe to state that the distinction among social intelligence, analytic intelligence, and creative intellect--captured in Guilford's model of the intellect and most recently underscored by Sternberg's triarchic theory of human intelligence--is generally held. The models definitely argue for a critical thinking, creative thinking distinction. It appears, notably, in Spearman's hierarchy of elementary processes, in Cattell's triadic theory, in Guilford's structure of the intellect model, and in Martinelli's and Nickerson's constructions. Fifth, there is a rebirth of interest evident in the recent work of Jaques, Biggs and Collis, and Van Hiele in degree of abstraction as a measure against which cognitive skills might be ranked as higher- to lower-order, a gradient eloquently articulated in the work of Spearman; used to order subclasses within classes in Bloom's taxonomy; and assumed as one of three dimensions in Guilford's model of the intellect.

There are, however, significant disagreements about important issues. These issues include the problem of intelligence, the place of creativity, the relative order of analysis and synthesis, and the role of evaluation.

Intelligence--that "generalized energy infusing the cortex" in Spearman's words, Biggs and Collis' HCS, and Jaques' cognitive power--remains the source of considerable controversy. As Jensen (1987) points out, intelligence has mainly three different meanings, each exclusively favored by different psychologists.

Some regard intelligence as the sum total of all mental abilities, or as the entire repertoire of a person's knowledge and skills at a given time. Others equate intelligence with *g*, or the more general factor common to all mental abilities. The contextualists claim that what any particular culture means by intelligence is only a selection of certain abilities from the entire cognitive domain, those particularly valued by the dominant culture. (Jensen, 1987, p. 194).

Nickerson clearly defines intelligence as everything but creative thinking. Nickerson is in sharp disagreement with Spearman, for example, who equates intelligence most with imagination and intellect, and Jensen, who, along with Spearman, is part of the second group identified.

It seems that the weight of empirical evidence is on the side of the second group identified. As Resnick observes (1976, p. 7), and in paraphrase of her words: **Although separate abilities as well as a general factor can be identified whenever a battery of cognitive tests is administered to a subject sample and a variety of laboratory and natural environment tasks can be defended as involving both "intelligent behavior" and separate abilities, the phenomenon of positive correlation among all of those scores and separate tasks remains one of the most stable findings in psychology.** It is this persistent result, occurring over decades from a variety of tests and tasks administered in a wide range of settings, that demands attention to the issue and nature of general intelligence. It may even be that a relatively small repertoire of fundamental cognitive processes are being tapped in various combinations. Equally interesting in this regard is the insistence by U.S. Army

three-and four-star Generals (interviewed 1985, U.S. Army Institute for the Behavioral and Social Sciences) on the importance of intelligence to the effective conduct of their professional obligations.

The position on intelligence accepted here agrees with the collective wisdom of those Generals and, just as importantly, with that of Jensen, Resnick, and Spearman. Thus, intelligence is a general cognitive capacity, or power, that infuses and informs the whole, standing in back of, so to speak, the cognitive skills deemed of interest here, much like the central figures of an Indonesian shadow play.

The place and importance of creative thinking in the construction of a comprehensive notion of human cognition is anomalous. It is at once affirmed, disregarded, or fenced. Clearest affirmations come from Spearman, Guilford, Cattell, and Nickerson. Gagne, on the other side, disregards the role of creativity altogether, basically concerning himself with information-processing and problem-solving behavior. Bloom and Sternberg recognize creative thinking but hold it apart. Bloom observes that the intellectual ability of synthesis "most clearly provides for creative thinking," but does not draw on the construct any further. Sternberg treats creative intellect as a superior but separate type of intelligence.

Among those affirming the place of creative thinking in the array of human mental abilities, there is disagreement about its relative importance. Spearman ranks it the highest-order ability. Allowing Bloom's equation of synthesis with creativity, it ranks second only to evaluation and exceeds analysis. Guilford, whose work has been closely identified with research and test development in the area of divergent thinking (or creative thought), ranks it third, after convergent thought and evaluation. In fact, he is most concerned about the lack of research and testing capability for convergent production and evaluation. His view on this point with regard to convergent production is reiterated:

In view of the apparent importance of convergent production abilities for any occupations in which rigorous thinking is involved--mathematics, logic, science, engineering, and law, to name a few--there is a need to push forward in the exploration of this whole area. (1967, p. 183).

Finally, Solmon and Rosen (1986), in testing the validity of the Bloom hierarchy, reported that high school students found problems in analysis and synthesis comparably difficult and significantly less difficult than those requiring evaluation. Cattell theorized that reasoning and creativity were powers to be ranked as equals.

Taking all those hard-won conclusions at face value, two educational implications may be drawn. One, critical thinking and creative thinking are important and distinct higher-order capabilities and may be presented as such. Two, critical thinking and creative thinking portions of a course series should be delivered one after the other, probably in that order.

Finally, if silence may speak louder than words, the place of evaluation in theoretical configurations of cognitive abilities is, if anything, more troublesome than that of creative thinking. It appears plainly in the models of only two theorists, Bloom and Guilford, both of whom agree that it is the most critical operation or process. Spearman's definition of judgment (1923, p. 87) edges very close: "putting together ideas or separating them from one another, in the mind, when their certain agreement or disagreement is not perceived but presumed so." Evaluation is cited and ranked highly by Nickerson (1990). For Martinelli, critical thinking subsumes evaluation. He defines critical thinking as the attempt to clarify meaning through the evaluation of evidence.

In Guilford's view, evaluation in all its aspects--absolute, relative, or disjunctive--is a neglected aspect of intelligence. He offers a plausible reason for its neglect. Psychometricians have ignored or overlooked it in part, he argues, because of the operational difficulty in differentiating evaluative abilities from corresponding cognitive abilities.... Indeed, evaluative tests have often employed forms analogous to those for deductive and inductive reasoning. Bloom suggests yet another plausible reason for the difficulty in dealing with evaluation theoretically.

Although evaluation is placed last in the cognitive domain because it is regarded as requiring to some extent all the other categories of behavior, it is not necessarily the last step in thinking or problem solving. It is quite possible that the evaluative process will in some cases be the prelude to the acquisition of new knowledge, a new attempt at comprehension or application, or a new analysis and synthesis. (1956, p.185).

Bloom touches on a key point here. The evaluative processes, in this opinion, occur recursively up and down the scale of higher-order cognitive processes, from appraisal of a piece of information in constructing a new internal representation of reality to critiquing a product of creative thought. Also, evaluative processes may be so poorly developed in most adults that they appear almost nonexistent, like a flickering trace. It is held here that evaluation has been elusive for these reasons.

There are major issues raised about which no disagreement is voiced: (a) Which is the better kind of model of cognition: interconnected grid, hierarchical dependency, or perhaps refined typology?; (b) What do the models with developmental overtones do for analysis of adult performance and development in educational settings and mentoring relationships? (c) What is the relationship between cognition and metacognition?

There are no quick and easy answers to these questions. The fact that the field is not in obvious disagreement on any one of them may be a sign that theory and practice have not grown sophisticated enough to warrant reasoned debate. It would seem, however, on the first point, that any model that considers the dynamic interactions among cognitive processes of the mind in action might have to combine elements of several. Two, from those models wedded to juvenile development, sequences of acquisition of cognitive abilities during

childhood and adolescence should be expected to yield predictable reflexes in adult behavior, for example, the more recently acquired capabilities being the most difficult as measured by accuracy, completeness, and speed in performance. Three, the state of the art vis-à-vis the relationship between metacognition and cognition is abject and confused. Metacognition variously defined is reduced in all but one of the models of cognition to a free-floating element. No one yet appears to understand fully the rules of engagement, so to speak, among metacognitive and cognitive elements. Recall Sternberg, 1979; Martinelli, 1987; and Gagné, 1985. Nickerson (1985) integrates metacognition directly with problem solving and, indirectly, with intelligence.

With respect to the study of adult cognitive development, certain obvious and nonobvious inferences may be drawn from the models reviewed. Six of the models treat and configure higher-order cognitive skills; they are most pertinent to the model of generic cognitive tasks and higher-order cognitive skills in preparation. These are the models of Spearman, Bloom, Guilford, Cattell, Martinelli, and Nickerson. Of these, Spearman, Bloom, Cattell and Martinelli expressly point to developmental correlates and implications. For example, Spearman explicitly references concept formation, judgment, and reasoning as a developmental sequence. However, these expressions are all confined to juvenile and adolescent development. The treatment, such as it is, is not as worthwhile as straightforward conversion of the inclusion relationships in the theoretical hierarchies into hypothetical progressive and cumulative developmental sequences at the adult level.

The Biggs and Collis, Van Hiele, Jaques, and Bucy models are also pertinent. By definition models of cognitive development, those constructions must be analyzed, appraised, and integrated in light of the higher-order cognitive skills addressed by the other six models if they are to be of any real use to the theory and taxonomy being devised here. The Biggs and Collis model begins to integrate its own organizing principles--those of abstractness, complexity (increasing number of organizing dimensions in response structure), and consistency in such usage--with the cognitive processes of generalization, induction, and deduction, tying in degrees of abstraction, complexity, and consistency with specific cognitive processes. It demonstrates, by means of the statistical studies cited above, that capability in simultaneous processing, or synthesis, significantly differentiates the unistructural, multistructural, and relational levels postulated theoretically.

The Extended SOLO Model expands the Piagetian stage model, in keeping with later Piagetian theory, and infixes the SOLO response descriptions differently, but the model no longer coheres with its earlier, organizing principles-cognitive processes intersects. The models of Jaques and Van Hiele, by contrast, hang much more on the organizing principles of degrees of abstraction and complexity and do not differentiate, apart from those principles, specific cognitive processes. Jaques' modes of reasoning roughly parallel Van Hiele's levels of thought, with two key differences. Jaques' levels of abstraction are more internally consistent; Van Hiele's are discontinuous. Van Hiele's levels 0 and 1 are distinctly perceptual in character, with level 2 being transitional, and levels 3 and 4 breaking into cognitive processes, with deductive reasoning clearly identified. It may also be that Van

Hiele's levels begin at an earlier stage of cognitive development than those of Jaques, whose five modes are not redefined by quintave. It should be interesting to see if these levels might be pieced together. In sum, almost 70 years later, the field has a model, in the Biggs and Collis taxonomy, that again attempts to relate degree of abstraction, as a defining principle of a hierarchical structure, with reasoning and creative processes, what Spearman (1923) did in his "hierarchy of elementary processes."

Now, to the ordered purposes of this inquiry--to determine, first of all, if viable theories, models, or taxonomies of human cognition exist in the empirical literature; second, if they do exist, to determine if they refute outright or in part, or affirm wholly or in part the preliminary taxonomy cast for test; and third, assuming some degree of affirmation, to determine if they assist conceptually in the development of the preliminary taxonomy. In brief, more models of human cognition were found to exist in the literature than had been expected. Moreover, the literature, though diverse theoretically and across time, offers support and neither duplicates, refutes outright, nor strongly disconfirms the preliminary taxonomy to describe requisite cognitive skills for executive leadership. The major purpose of this research was to find persuasive disconfirming evidence.

The principal expectations a priori were that

- . there would be no close approximations of the preliminary taxonomy, and in fact there were none;
- . there would be some degree of affirmation, and there was;
- . and those models that do exist would be different or sufficiently incomplete that they would not materially aid the configuring of the preliminary taxonomy. That expectation was not borne out. The literature did afford considerable clarification in the development of the taxonomy on the matters of evaluative and creative processes and the roles of intelligence and degree of abstraction. On the other hand, there is no taxonomy of requisite cognitive skills for any kind of expert performance, let alone expert executive performance, though Mumford's listing (1986) makes an attempt.

First and foremost, the taxonomy's generic cognitive tasks--creative thinking, problem solving, and mapping ability--are recognized repeatedly in the models reviewed. The logic going into the analysis of the psychological literature was that the weight of the evidence should serve as signposts. It has, and it indicates the essential choices are right. Second, the relative placements of the generic tasks and higher-order cognitive skills are congruent with the literature. Table 10 and accompanying observations make the point.

Models are excluded from the comparison in Table 10 for several reasons. Spearman concentrated much more on analyzing higher-order cognitive processes than either Burt, Vernon, or, for that matter, Thorndike. Cattell rank orders crystallized intelligence,

TABLE 10
The Higher-Order Cognitive Processes Identified in Five Models

Spearman (1923)	Bloom (1956)	Guilford (1967)	Nickerson (1985)	Martinelli (1985)
Creativity	Evaluation	Evaluation	Creative Thinking	Problem Solving
Reasoning	Synthesis	Convergent Thinking	Critical Thinking	Critical Thinking-Creativity
Judgment	Analysis	Divergent Thinking	Reasoning Ability-Problem Solving	Reasoning Ability
Concept Formation			(Application)	
Memory	Remembering/ Comprehension	Memory		
	Knowledge	Cognition (having information and comprehending it)		
[I N F O R M A T I O N P R O C E S S I N G]				

reasoning, and creativity equally. Gagne is fixed on problem solving. The models of Sternberg (1979), Bucy, Jaques, Van Hiele, and Biggs and Collis are likewise narrowly focused. Vandendorpe does not attempt a configuration of mental abilities. Though very different from the Vandendorpe model, neither do the taxonomies of Fleishman or Mumford et al.

The parallels among the five models in Table 10 are striking. For instance, the parallels between all of Guilford's "operations" and Bloom's "outcomes" would be isomorphic, save for Guilford's reversal, in the divergent-convergent thinking sequence, of Bloom's ordering of analysis and synthesis. As to the placement of knowledge in Bloom's taxonomy (comparable

to a constructed knowledge domain), Bloom appears to be speaking for the group in a voice that seems to echo across time:

Problem solving or thinking [evaluation, synthesis, and analysis] cannot be trained in a vacuum, but must be based upon knowledge of some reality. (Bloom et al., 1956, p. 33).

Certainly the two most basic cognitive processes in his hierarchy, remembering and comprehending, as defined, are aspects of information processing, which undergirds the higher-order processes identified in the preliminary taxonomy being constructed.

More pointedly, the preliminary taxonomy is indebted to the cognitive theory of Elliott Jaques for its conception of mapping ability. Cognition, according to Jaques, involves the combination of elements into meaningful patterns (Jaques, 1985, p. 111). It is the ability to create, manipulate, and interpret those combinations as mental representations and incorporate them into an operational map of reality. In fact, cognitive power is defined as "the mental force a person can exercise in processing and organizing information and in constructing that map." (Jaques, 1985, p. 107). The greater the cognitive power, the more extensive and more complex the individual's model of reality.

However, one jarring placement keys the omission of planning and many of the cognitive processes held to underlie it from the empirical literature treating cognitive models. That is the placement in Bloom's taxonomy of extrapolation under comprehension. In Bloom's view, comprehension is the basic intellectual skill. The ability to extrapolate -- as Bloom defines it, "the making of estimates or predictions based on understanding of the trends, tendencies, or conditions described in communication" -- seems a severe criterion for comprehension. Extrapolation seems out of place, and better allied with the battery of skills identified with the task of long-term planning. Guilford comes closest to the concept of long-term planning offered herein in his consideration of the intersect cognition of implications. Guilford defines implications as "close to cause-effect relationships" (1967, p. 104) and then explains that expectancies, anticipations, and predictions are emphasized by the intersect. Continuing, he explains that, whereas in formal logic the paradigm of antecedent-consequent is locked in, implications drawn from real-world situations can only be probabilistic.

In other respects, the preliminary taxonomy is unlike anything in the empirical literature to date. The taxonomy is a composite. It is componential, but not in the sense of Vernon and Spearman because of its cross-cutting factors. It is hierarchical in nature. Thus, it shares features of both major taxonomic types. It adopts the cognitive task analysis approach, outlined by Sternberg (1979). It is already more detailed in its enumeration and grouping of underlying cognitive processes than any model reviewed to date, with the notable exception of Guilford's taxonomy. It is, moreover, deeply concerned with underlying processes and their interaction vis-à-vis the generic cognitive tasks of interest. With the exceptions of Cattell's triadic theory and Vandendorpe's k-d Tree and despite a fascinating discussion on the subject of interactive cognitive processes by Bloom, the models reviewed are static. That is why a

taxonomy of cognition should be two-fold, with one representation showing the fundamental ordering by complexity of the cognitive processes entailed, and the other showing the likeliest workings and interactions among them.

The taxonomy under development will be used to identify and classify the underlying cognitive processes requisite to the performance of certain cognitive tasks. To ensure this, an abilities requirements approach will be taken in developing the taxonomy. This approach appears to represent a synthesis of cognitive (abilities theorists) with organizational psychology because the approach seeks to identify categories of abilities and then determine the relationships of those abilities to each other and to performance on specific tasks said to require certain ability profiles if performance is to be maximized with respect to established criteria. Specifically, it is held that effective strategic leadership is best understood by studying the underlying organization of the thinking used to construct a useful internal representation of reality, solve problems, plan in the abstract over the long term, and produce creatively. Toward further definition in that regard, partonomies of human cognition in the empirical literature should be probed.

THE PRELIMINARY TAXONOMY OF GENERIC COGNITIVE TASKS AND HIGHER-ORDER COGNITIVE SKILLS

In this taxonomy, four complex, generic cognitive tasks are posed as requisites to effective executive leadership: **mapping ability, problem management/solution, long-term planning, and creative thinking**. These were inferred after appraisals of the empirical literature on executive leadership and human cognition. Each of the tasks was analyzed into hierarchically organized components, again using a theoretical deductive approach. The notion of a hierarchical taxonomy of higher-order cognitive skills resting on component cognitive elements has precedent (Spearman, 1923). However, in this taxonomy, component higher-order cognitive processes cross-cut generic tasks, which are thereby connected. Thus, the taxonomy shares features of hierarchical and lattice constructions. The degree of importance assigned to information-processing components, likewise cross-cutting and underpinning these major cognitive tasks, is drawn from the empirical work in that field.

Mapping Ability

As has been noted, Jacobs and Jaques argue at length for the importance of mapping ability. "The executive must in theory be able to build into his frame of reference enough [emphasis added] cause and effect chains to enable inference to the overarching [emphasis added. Implication is to ordinate-subordinate structure] rules and principles that pertain to the [organizational] system at this level." (Jacobs and Jaques, 1990b, p. 283). Thus, "executives should have much broader perspectives (causal maps) than incumbents at the organizational level [roughly, middle level of management in a bureaucracy]." (Jacobs and Jaques, 1990b, p. 287).

In the opinion of Jacobs and Jaques, the requirements for mapping ability increase by organizational level. The higher the organizational level is,

the greater the

N of interdependent elements--i.e., causally related, moderating, or intervening;

Complexity of the interdependencies, including contingent features probabilistic in nature;

Rate of change of interdependencies over time;

Variance in the timing of antecedent events;

N of events produced in parallel by parallel or competing strategies;

N of events either hidden or disguised;

the longer the time interval required to identify a cause-effect chain;

the greater the degree of uncertainty with which the effects can be known.

Problem Management/Solution

As to the relative importance of problem management in the array of an executive's cognitive capabilities, as defined herein (this report, p. 80) "it may well be the highest priority task at the executive level." (Jacobs and Jaques, 1987, p. 23). Peterson and Rumsey (1981) have described problem solving as a generic skill that emerges repeatedly from research on occupational and life tasks. Problem solving is conceived as an overarching skill that subsumes critical inquiry, self knowledge, and communication. Critical inquiry, in turn, is assumed to subsume analysis and synthesis. Further, Jacobs and Jaques note that accounts of successful executive decision making do not really seem to depict decision making in the conventional sense of the term, but instead, problem management and solution.

The [executive] approach to decision making is also different and more challenging. It appears not to be selection from among formulated alternatives [cf: classification problem solving] based on an advantages-disadvantages comparison, but rather the formulation of "workable" solutions to problem situations which are difficult to fathom. (Jacobs and Jaques, 1990b, p. 293).

In other words, a proactive stance that works on the basis of a hypothesis about the solution is shaped by successive approximations toward the ultimately 'good' solution as more data come in and the situation becomes clearer. "The executive approach is to develop a workable

course of action and then to manage [emphasis added] the outcome over time so that it will be successful." (Jacobs and Jaques, 1990b, p. 293).

Long-Term Planning

In 1981 and 1982, the Army War College examined the state of planning in the U.S. Army and concluded that the ability to develop effective and executable plans, particularly in innovative and nontraditional modes, was deficient. Part of the problem was attributed to the operationally permissive environment during the Vietnam conflict that failed to reinforce the need for thorough and logical planning. But the crux of the problem was thought to be that military schools were not teaching officers how to think, plan, and decide [emphasis added]. In his appraisal of the three areas of concentration necessary to the development of military leaders--character, know-how and practical leadership, and military judgment and analytic skills--General William R. Richardson, U.S. Army, then Commander of the U.S. Army Training and Doctrine Command, wrote

The third area where expertise is needed is that of military judgment and analytical skills.... Why do so few soldiers think? Because so many have never been taught to do so....

Today, we must emphasize how to think rather than what to think.... Officers must know how to make an estimate or an appreciation of the situation, how to decide alternative courses of action, and how to write a concept of operations. (Richardson, 1984, p.33).

Others have drawn similar conclusions. The ability to envision multiple futures and anticipate their consequences vividly may be crucial to effective military planning at corps level and at echelons above corps (Markessini, 1987). Stamp (1988), in speaking about corporate leadership, asserts: "The exercise of discretion may be thought of as the imagination, formulation, and execution of a course of action which is not prescribed [emphasis added]." (Stamp, 1988, p.6).

The central issue, for leader development purposes, is the skilled exercise of decision discretion. It is of course apparent that the Schools must teach what to think as well as how to think. It is from the "what" that broadened perspectives and richer frames of reference come. However, the temptation -- because it takes less energy -- is to teach "what" in the absence of "how." That, unfortunately, produces a climate in which the right response is to regurgitate that which has been previously given, without modification. That, in turn, will produce students who are less proactive and, almost by definition, less adept at application of the new operations doctrine now being fielded. "How to think" implies decision discretion and subordinate empowerment as much as it does skilled cognitive processing; it is difficult to have one without the other.

Creative Thinking

Finally, "Leadership at its best comes close to creativity." (Cronin, 1984, p. 25). Simon (1977) notes

Executives spend an ever larger fraction of their time seeking to invent, design, and develop possible courses of action for handling situations,... larger even than the large fraction of their time used to survey the political, social, economic, and technical environments to identify new conditions that call for new actions. (Simon, 1977, p. 40).

Yet, creative thinking is hardly a topic with which traditional disciplines in traditional colleges are comfortable--especially fields of study like business administration and the martial arts. Cronin offers an explanation for the discomfort. Much of creative thinking calls upon unconscious thinking, dreaming, and fantasy--still virtual taboos in the world of hard-edged, rational decision making. No less a proponent for creative thinking as both a must in the repertoire of cognitive skills for military executives and the highest order of cognitive skill in a hierarchical taxonomy of cognition is Charles Spearman (Spearman, 1923, p. 337). Spearman comments: "The fault of assuming imagination to be a separate power [i.e., unrelated to other higher cognitive processes] does not lie in too high but in too low an estimate of cognitive creativeness." As to the reason why creative thinking "has not been detected," ... "this would seem chiefly due to the difficulty of psychological analysis." (Spearman, 1923, p. 388).

In sum, the generic cognitive tasks considered critical to and distinctive of effective functioning at the highest executive levels are **mapping ability, problem management/solution, long-term planning, and creative thinking.** Affirmation of this election has been drawn from the empirical literature in the behavioral sciences and from preliminary results of a content analysis performed on the ARI General Officer interviews. Nickerson (1990, p. 11), for example, has in fact identified as "higher-order cognitive skills" "reasoning, problem solving, decision making, planning, composing [creativity, surely], evaluating, learning" in that order, although he has not devised a taxonomy for them. There is likewise support for this specification of cross-cutting component cognitive processes. For example, the ordinate-subordinate relationship posited for the processes of evaluation, synthesis and analysis is instantiated fully in the taxonomy of Bloom (1956) as "evaluation," "synthesis," and "analysis," but not in Guilford (1967), who calls it "evaluation," "convergent production," and "divergent production," respectively.

Further, there is ample evidence that the U.S. Army three- and four-star Generals interviewed pay attention to and value cognitive skills in their own right and as essentials in the effective conduct of a General Officer's role. In fact, the assertions of the General Officers evaluated to date support the selection of the cognitive tasks and skills presented. Most of their assertions on cognitive tasks fall into the categories of mapping ability, problem management/solution, long-term planning, and creative thinking, as defined in the taxonomy. Other component processes and skills identified in the taxonomy are also in evidence and certain connections--for example, between long-term planning and creative thinking--are being

asserted. Problem solving is, by the preponderance of the references to it, considered the key to executive leadership. Planning is viewed as necessary but secondary. Creative thinking is considered fine, by and large, but a "little goes a long way." Creativity is championed only by the more intellectual of the Generals (indicated by the individual officer interviews), is present in the statements by others, and is considered somewhat troublesome by a few. Illustrations of the extreme positions are given.^{1,2}

Most important, the four generic tasks have been chosen because, although they may be thought to be part of the human repertoire at all levels of capability, however that is measured, they are nonetheless held to be essential, perhaps even defining, skills of effective executive leadership and their practice is thought to be qualitatively and quantitatively of a different order at that level. Brief descriptions of each of the four appear in Figure 14.

The distinctive features of this taxonomy in brief are

- Particular **generic cognitive tasks** chosen;
- View that they are highly complex, nth-order skills tantamount to real-world cognitive tasks such as planning;
- Progression among these high-order cognitive tasks from least to most complex: mapping ability, problem management/solution, long-term planning, and creative thinking, with creative thinking more removed from the first three;
- Use of information-processing abilities and high-level reasoning skills to cross-cut and interconnect the highest-order generic cognitive tasks;
- View of planning as the quintessential executive skill, in that it is both a turning point in marking the "true executive" and a nexus for the generic cognitive tasks of problem management/solution and creative thinking;
- Distancing of creative thinking from the first three tasks by its placement on a dimension, voluntary control, over cognitive functions;
- Tying in of creative thinking with the so-called "analytic" capabilities of problem management/solution and planning via the link of mapping ability and with planning via the shared skill of imagination (in planning, specifically, the envisioning of multiple futures thought to be requisite to it); and
- Importance of information processing as a high-level base.

NOTES -- SECTION I

¹**Wisdom** combines many cognitive capabilities and should be considered a highest-order cognitive skill. It is here defined as great knowledge tempered by both a keen practical sense and the power to discern acutely, so that proper and prudent judgment about what is true and right can be rendered and acted upon accordingly.

²**Cognition** is any mental process that involves abstraction, including complex rule use, problem solving, insight, symbolizing, and imagery.

³**Metacognition** is the capacity to know and think about one's own cognitive processes, a capacity that can be used voluntarily to regulate thought. It is an aspect of reflective self-awareness. Metacognition, like other forms of knowledge, undergoes systematic changes with development and is thought to improve with age. Metacognitive strategies range in complexity from the simplest memory aids to strategies so complex they challenge, if not defy, description.

⁴**Generic Cognitive Tasks** are more like the meta processes said to underlie general intelligence. They are here exemplified by mapping ability, problem management/solution, long-term planning, and creative thinking.

⁵**Higher-Order Cognitive Processes or Skills** are traditionally defined as concept formation, reasoning (inferencing and judgment), problem solving, and language.

⁶**Component Cognitive Skills** are, e.g., pattern recognition, auditory recall, spatial relations. These will not be evaluated here as independent entities but rather as pieces of the higher-order processes.

⁷**Metacognitive Skills**

Awareness of--

Independent cognitive processes

Cognitive style (as operationalized, for instance, in the MBTI, Myers-Briggs Type Inventory)

How one's own (cognitive) characteristics interact with relevant situational characteristics

Executive Functions--Use of

Self-Management of the learning process

Knowing what you know, do not know, and need to know

Learning about learning

Learning to learn

Reflection upon experience: Creates new knowledge and sometimes builds models without concurrent direct experiences

Executive Functions--Strategic Control

⁸New conceptual requirements [for leaders] do not replace those of earlier levels but, rather, are superimposed on them. (Jacobs and Jaques, 1990b, p. 282)... "The [Stratified Systems] theory also suggests that decisions, and therefore the required thinking skills, may also be qualitatively different in nature at successively higher echelons [emphasis added]." (Jacobs and Jaques, 1990b, p. 283.)

NOTES -- SECTION II

¹The "Condensed Version of the Taxonomy of Educational Objectives" (Bloom et al., 1956, pp. 201-207) follows, pages 69-71.

²**Discrimination Learning** is learning in which n different identifying responses are made to as many different stimuli that may resemble each other. Individual chains connecting each distinctive stimulus with each identifying response must be learned.

³**Signal Learning** is learning in which a stimulus becomes a signal for the reaction prompted by a different stimulus closely associated with the first stimulus. The reaction is generally a diffuse emotional one.

⁴**Intelligence**

In Jensen's considered opinion (Jensen, 1987), intelligence should be equated with only the g factor derived from a hierarchical factor analysis of a large number of diverse mental tests representing the whole domain of known mental abilities.

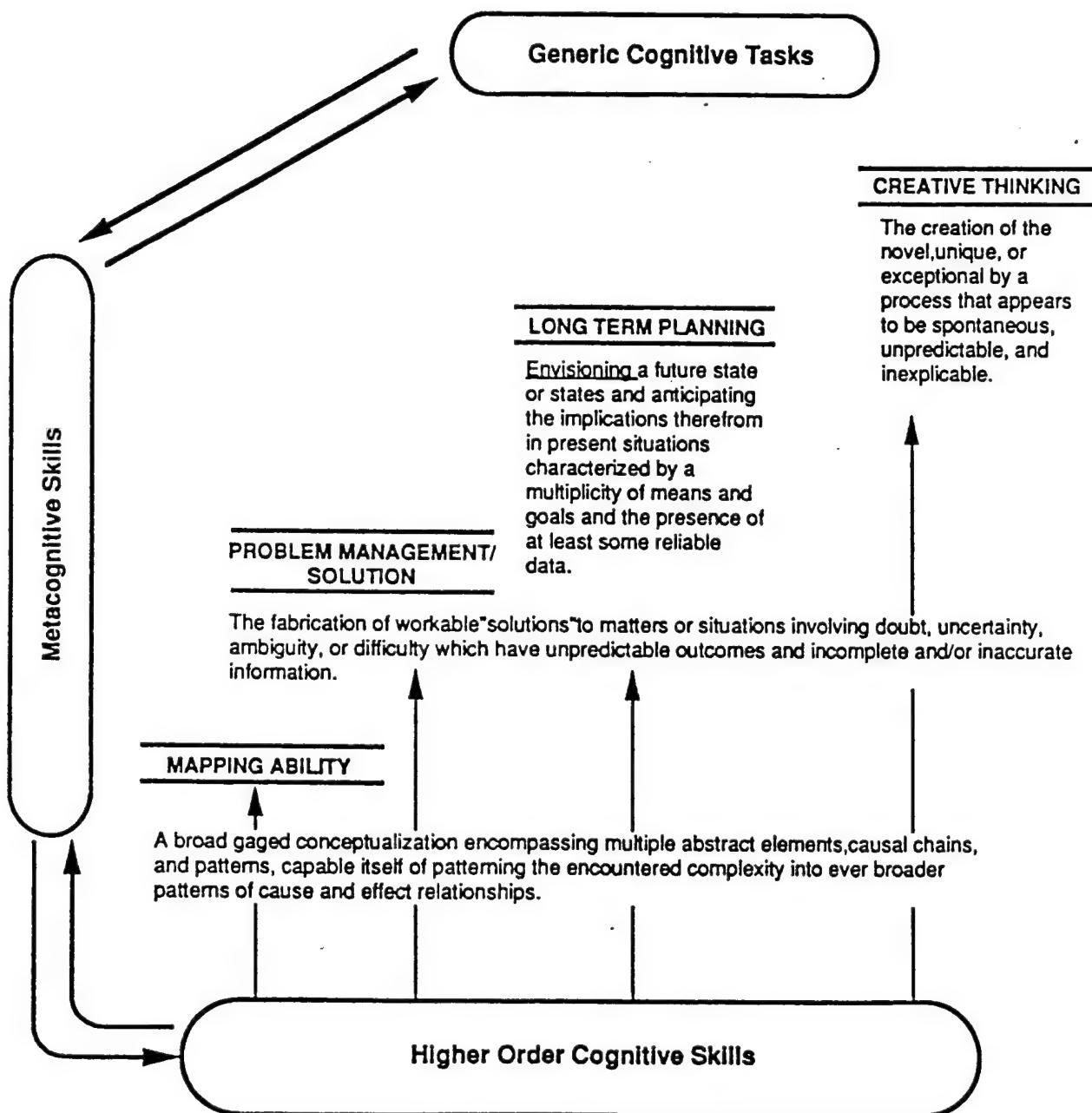


Figure 14. Generic cognitive tasks, simply defined

NOTES -- SECTION III

¹A U.S. Army Lieutenant General on Creativity

"There is a very interesting book written by Edmund Wilson, not a book but a long essay, called 'The Wound and the Bow.' This has to do with Philoctetes, who in Greek mythology was a wounded warrior. He lived on this island with a stinking gangrenous wound that never went away. But he played the lyre or the bow. And he made beautiful music, but that beautiful music was associated somehow with the need to do that, to offset the stinking wound.

"There has been a book written recently that talks about artists. And it says that if you look into most artists, they are unbalanced; in fact, a lot of them end up being crazy. It is the imbalance that causes them to do this great art. It is trying to compensate for some kind of imbalance that is in there.

"Well, to put that in a more vernacular sense, I have always considered myself and [LTG (Name Withheld)], I have considered us, to be square pegs in round holes. I rather take it to be a round peg in a square hole. You know, I would rather be a round peg in a square hole than a round peg in a round hole. I think that it is better in your life time.

"Another way to put it, which is very vernacular, is, we have always said artists need to suffer. There is something about this. What we are really saying is 'development.' How does development come about? Development requires motivation. You might be motivated by your stinking wound. You might be motivated by the friction of the square hole on your round peg. You might be motivated by your suffering and your need to get over that. But there is a developmental motivation that is required. And so, it is not a bad idea to take some of our square pegs and cram them into round holes every now and then. In fact, we need to do that."

In essence, this Lieutenant General believes that the military needs the wellspring of developmental pain (whatever that may be) to motivate creativity and professional development.

²A U.S. Army Lieutenant General on Creativity: Contrasting Opinion

"If you want to innovate, just check Webster's. Innovators are guys who know what the rules are and have a base from which to innovate. Being an innovator to some of these youngsters,... If we tell them today to go out and make your mistakes and innovate, and all that, usually you will find that they are winging it. What we should do is say, 'Do it right or I will give you a kick, and start learning.' Somebody has to guide them and tell them that. I am not sure we do enough of that."

This Lieutenant General begins well, then moves to a position in which he espouses punishment for innovation demonstrated by young soldiers. At the outset, he appears to agree with a statement credited to Ernest Hemingway in his advice to young writers: You must first know the rules before you can depart from them. At the end, his opinion on how to foster innovation in novice or would-be military officers appears painfully clear.

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GLOSSARY OF TERMS

Ability, Capability, Skill, Trait

Aptitude--an inborn or acquired inclination--both capacity and propensity--that is special, toward certain related courses of action or behaviors.

Cognition--any mental process that involves abstraction, including complex rule use, problem solving, insight, symbolizing, and imagery.

Complexity--the presence of any secondary set of factors that functions to increase the intractability of a solution.

Component Cognitive Skills--e.g., pattern recognition, auditory recall, spatial relations. Subordinate elements of higher-order cognitive processes.

Concrete Reasoning--reasoning that is strongly tied to context or to immediate and tangible information.

Creative Thinking--the creation of the novel, unique, or exceptional by a process that appears to be spontaneous, unpredictable, and inexplicable.

Critical Inquiry--the ability to both piece together information and infer more meanings.

Amorphous--diffuse, undefined, having no specific shape or structure. Having structural components that are not clearly differentiated.

Analysis--separating out the essential elements from a situation or problem; to detect, identify, and pull abstract patterns from the flux of information.

Approximate Implication--a type of judgment, reasoning, or decision making that entails selecting the most probable among possible futures; i.e., A suggests B, or C and D tend to rule out E; therefore,... It also entails calculation of changes in people, places, and materials over time and the use of contingencies, as the likelihood of distant futures may depend on nearer but unpredictable events. Prediction is a kind of approximate implication.

Aptitude--an inborn or acquired inclination--both capacity and propensity--that is special, toward certain related courses of action or behaviors.

Cognition--any mental process that involves abstraction, including complex rule use, problem solving, insight, symbolizing, and imagery.

Complexity--the presence of any secondary set of factors that functions to increase the intractability of a solution.

Component Cognitive Skills--e.g., pattern recognition, auditory recall, spatial relations. Subordinate elements of higher-order cognitive processes.

Concrete Reasoning--reasoning that is strongly tied to context or to immediate and tangible information.

Creative Thinking--the creation of the novel, unique, or exceptional by a process that appears to be spontaneous, unpredictable, and inexplicable.

Critical Inquiry--the ability to both piece together information coherently and accurately and to separate out the essential elements from a situation in order to enhance comprehension of it.

Deduction, Induction, Analogical Reasoning

Deduction--reasoning that begins with a specific set of assumptions and attempts to draw conclusions or derive theorems from them. In general, it is a logical operation that proceeds from the general to the particular. Deductive inference requires no verification other than logical consistency. The proof is in the appropriateness and demonstrability of the conclusions that are deduced. Thus, a conclusion may be valid but untrue.

Induction--reasoning in which general principles are inferred from specific cases. In general, it is a logical operation that proceeds from the individual to the general; what is assumed true of elements from a class is assumed true of the whole class. As an example, the experimental method is inductive in nature; conclusions about populations are drawn from observations of individuals and small samples.

Related to **Analogical Reasoning**--the ability to see likenesses (that most people miss). A is to B as C is to ?.

Discrimination Learning--learning in which n different identifying responses are made to as many different stimuli that may resemble each other. Individual stimulus-response chains connecting each distinctive stimulus with each identifying response must be learned.

Disorder--disruption of an order once present or still thought to be appropriate.

Divergent and Convergent Thinking

Divergent Thinking--thinking that is characterized by movement in various directions, not necessarily systematically; a diverging of ideas that encompasses a variety of ultimately relevant aspects. Often associated with **Creative Thinking**.

Convergent Thinking--thinking that is characterized by bringing together information and knowledge focused on a solution to a problem, particularly one with a single best solution. Often associated with **Problem Solution**.

Equivocal--inadequate quality, fuzzy.

Evaluation--determination of the value, worth, or appropriateness of a thing, material, or abstraction (idea, concept, principle, work, solution, method) for some purpose (e.g., an explanation of some phenomenon) by such criteria as identity, similarity, consistency, or, more broadly, aesthetic or ethical criteria.

Generic Cognitive Tasks--more like the meta processes said to underlie general intelligence, they are here exemplified by mapping ability, problem management/ solution, long-term planning, and creative thinking.

Guessing--a choice, decision, or judgment seemingly at random in circumstances in which an individual is unfamiliar with the nature of the data or the data are fragmented or virtually absent, the probability of a correct guess being affected by unconscious perceptions and reasoning. The assumption is that a starting point, any starting point, is better than none.

Higher-Order Cognitive Processes or Skills--traditionally defined as concept formation; reasoning, inferencing and judgement; problem solving; and language.

Hypothetical Reasoning--reasoning from a set of fictitious but possible circumstances--"What if...?"--often where there is a multiplicity of means and goals.

Imagination, anticipatory or reproductive--the recombination of remembered experience and prior images into new mental constructions, generally a creative process. It may be largely wishful or largely reality bound.

Information Processing--the scanning; search; organization (including abstract pattern discrimination and abstract pattern building); and interpretation (coding, recoding, and decoding) of any input, whether ideas, images, facts, or sensory stimuli.

Intelligence--the common factor derived from a hierarchical factor analysis of a large number of diverse mental tests representing the whole domain of known mental abilities.

Intuitive Reasoning--characterized by speed, focus, and reasoning that is largely unconscious. Acute sensitivity to situational cues subliminally processed and speeded processing of internal knowledge structures are features.

Learning--a change in human disposition, capacity, or behavior under certain specifiable conditions that persists and is not simply ascribable to processes of growth.

Mapping Ability, Cognitive Map, Templating Model

Mapping Ability--a broad-gaged conceptualization encompassing multiple abstract elements and causal chains and patterns, capable itself of patterning the encountered complexity into ever broader patterns of cause and effect relationships. Includes both the representation and structure of the conceptualization and the information-processing capabilities by which its modification transpires.

Cognitive Map--as originally defined by Tolman, an image-like spatial representation, and the mental analogue of a real map, of a physical layout. (Some later theorists use this term as synonymous with "mental map.")

Templating Model--a model of pattern recognition that assumes novel stimulus patterns or events are processed by matching them against templates (internal mental map representations) stored in memory until a match is found.

Metacognition--the capacity to know and think about one's own cognitive processes, a capacity that can be used voluntarily to regulate thought. It is an aspect of reflective self-awareness. Metacognition, like other forms of knowledge, undergoes systematic changes with development and is thought to improve with age. Metacognitive strategies range in complexity from the simplest memory aids to strategies so complex they challenge or even defy description.

Partonomy--a taxonomy for components of particular generic cognitive tasks or higher-order cognitive skills.

(Long-Term) Planning--envisioning a future state or states and anticipating the implications in present situations; characterized by a multiplicity of means and goals and the presence of at least some reliable data.

Problem Management/Solution--the fabrication of workable "solutions" to problems--i.e., matters or situations involving doubt, ambiguity, uncertainty, or difficulty--that have unpredictable outcomes and incomplete and/or inaccurate information.

Reasoning--a coherent, higher-order cognitive process in which hypotheses or premises are advanced and inferences drawn.

Reasoning by Elimination--a conservative approach to inferences and conclusions in which every interpretation apparently consistent with the data is found and systematically considered and those inconsistent with the data are ruled out. Such reasoning is appropriate under certain circumstances; for instance, to an attorney preparing a case for trial. Also known as **exhaustive search strategy**.

Resolution--the drawing of inferences and workable conclusions based on coordination of all relevant elements and integration of otherwise fragmented, insufficient, or confusing information (insufficient here means not enough to support or refute definitely). It requires sensitivity to fluctuation in the input data, use of diverse data, and use of diverse data sources.

Signal Learning--learning in which a stimulus becomes a signal for the reaction prompted by a different stimulus closely associated with the first stimulus. The reaction is generally a diffuse, emotional one.

Simplifying Assumptions, Use of--informed, reasoned, and principled simplification of situational uncertainty, volatility, ambiguity, amorphousness, complexity, and disorder in preparation for decision, plan, or communication to peers or subordinates. The "reduction to the absurd" of formal logic illustrates both a simplifying assumption and consequence of its use. This is important in planning when problems must be bounded rapidly and basic parameters defined quickly.

Successive Approximations, Use of--a reasoning strategy in which a potential solution to a problem is shaped successively as information becomes available and a problematic situation becomes clearer. It may be used in the problem analysis or solution implementation stages of problem management.

Synthesis--the ability to piece together information bits coherently, constantly correcting working hypotheses as new information comes in to form a composite model or models. Parallels abstract pattern building. Also known as **integration**.

Theory, Model, Taxonomy, Typology

Theory--strictly speaking, a coherent sequence of formal expressions that completely and consistently characterizes and explains a field of investigation, its attendant facts and empirical findings. The theory should begin with a set of terms and axioms, which are then used to deduce theorems that are evaluated for their ability to encompass known facts and predict new phenomena. More broadly (and more characteristically in disciplines like psychology), a theory is a system of interrelated general principles given in explanation of known facts and empirical findings.

Model--a mini-theory, the utility of which should be assessed by the predictions that can be drawn from it and the guidance it affords research and the development of theory in a given field. It is a representation that reflects, imitates, or illustrates in an idealized way systems or relationships derived from data or observed in the natural world. In that a model may be mathematical as well as mechanical or structural, it is generally superior to a taxonomy.

Taxonomy--a structural model organized by a set of consistent principles that dictates the elements within it. It is not, therefore, a serial listing of items or units. The structural rules or principles of a taxonomy are more complex than those of a classification system. A taxonomy must be testable by determining whether or not it is consistent with the empirical evidence and/or sound theoretical positions in the field and it must be predictive of phenomena yet to be discovered.

Hierarchical Taxonomy--a taxonomy composed of classes within classes of increasing generality. Just as animals can be classified by this scheme, human task performance, hypothetical psychological processes, and mental tests can be classified in terms of both common and distinguishing attributes. The inclusive relationships of a hierarchical taxonomy of cognitive processes are often used to account for intellectual growth.

Typology--a classification system for types of, for example, personality or behavior in which various instances are grouped according to specifiable criteria and where the groups are disjoint.

Tolerance of Uncertainty, Complexity, and Ambiguity--making and retracting assumptions, recognizing that in any planning process some assumptions will fail and accepting, at least tentatively, conclusions for which the proof is unreliable, equivocal, or insufficient.

Uncertainty--the degree to which there are no constraints upon the available choices.

Unreliable--not yet proven true or false but suspect.

Volatile-- highly changeable, a fluid state.

Wisdom--a highest-order cognitive skill combining many cognitive capabilities. Great knowledge tempered by both a keen practical sense and the power to discern acutely, so that proper and prudent judgment about what is true and right can be rendered and acted upon accordingly.